Virginia's BLUE CRAB POT FISHERY:

The Issues & the Concerns

ANNE RHODES

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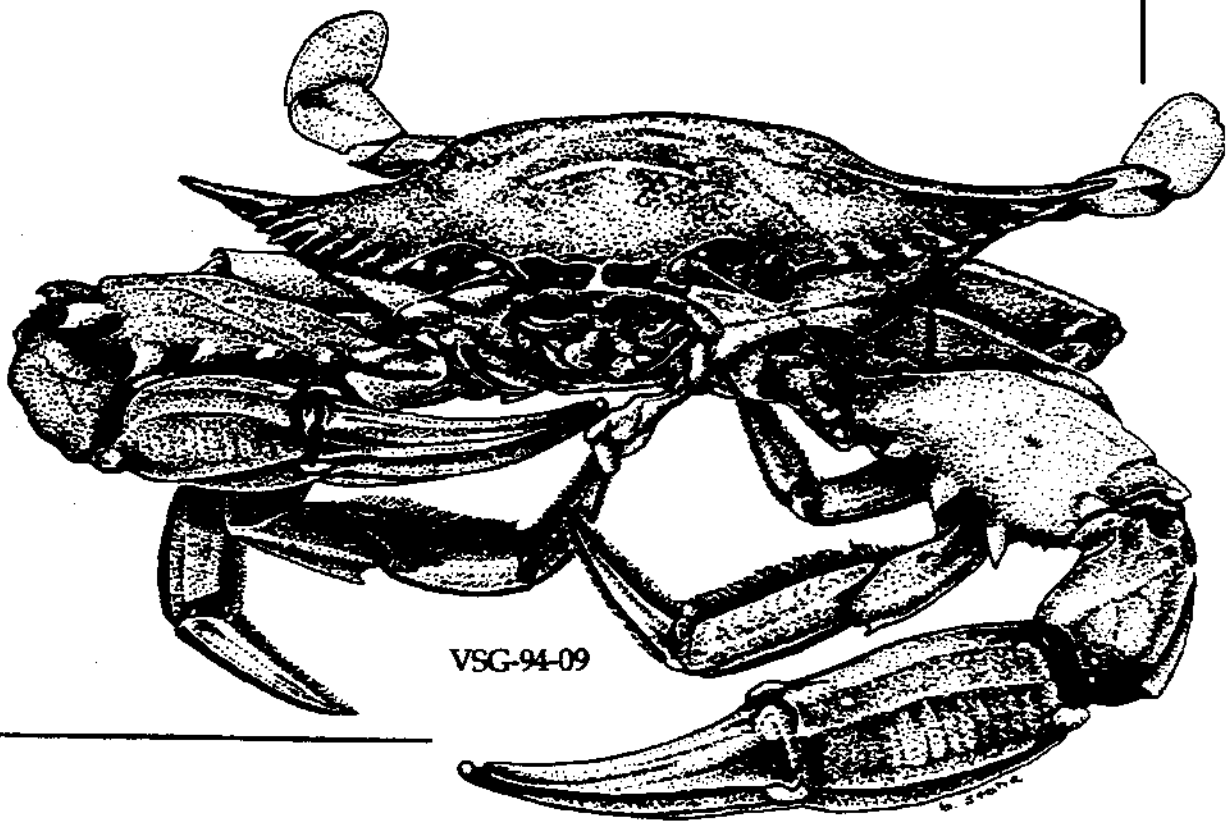

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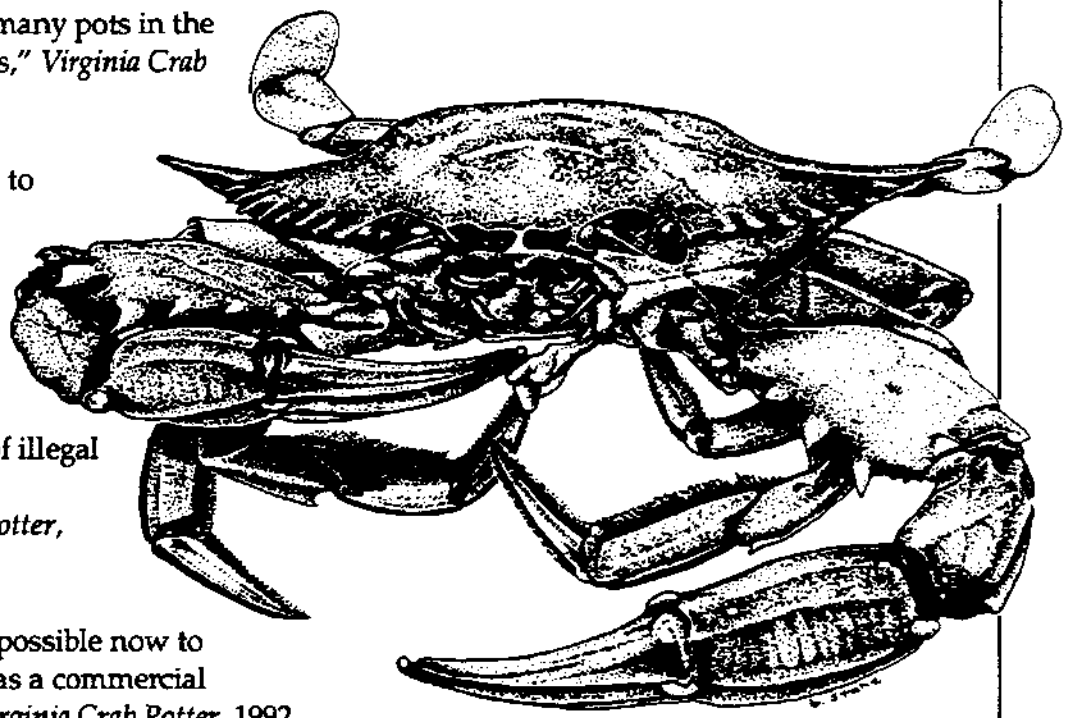
- "Chesapeake Bay Woes Feared Catching Up to Crabs," Headline, *Washington Post*, July 1991.
- "We don't need new regulations, we just need someone to enforce the existing ones," *Virginia Crab Potter*, 1992.
- "There are too many pots in the Bay and Rivers," *Virginia Crab Potter*, 1992.
- "The price paid to watermen is fixed," *Virginia Crab Potter*, 1992.
- "There is a lot of illegal crabbing," *Virginia Crab Potter*, 1992.
- "It is almost impossible now to make a living as a commercial fisherman," *Virginia Crab Potter*, 1992.



- "Crabs have remained scarce this season," *Rappahannock Record*, July 1992.
- "We need to stop crab dredging in the winter and also do away with peeler pots," *Virginia Crab Potter*, 1992.
- "This year wasn't a good year for crabs, " *Virginia Crab Potter*, 1992.
- "Maryland, Virginia move to restrict blue crab harvests," *Bay Journal*, July 1993.
- "Crab harvests at low ebb,"*Rappahannock Record*, April 1993.
- "There are too many retired people crabbing," *Virginia Crab Potter*, 1992.
- " Virginia Authorities Try to Slow Plummet of the Crab Crop," *Washington Post*, June 1993.
- "Need to have a closed season for crabs," *Virginia Crab Potter*, 1992.

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Low harvest levels, low prices, and too many pots are just a few of the concerns that have been expressed for Virginia's blue crab fishery. The comments and headlines indicate that there has been much discussion of these concerns over the past few years, coming from fishery managers, the watermen who harvest the crabs, and the general public who are all concerned about losing one of the Chesapeake Bay's premiere resources.

Why Is There Concern?

Historically Maryland and Virginia have provided between 45 and 55 percent of the U.S. hard blue crab harvest and over 60 percent of the soft crab catch. In recent years, the blue crab has become the main source of income for Virginia's watermen, as harvests of oysters and finfish have declined (see Figure 1). Over the last two decades, total harvest of blue crabs has fluctuated, but shows no systematic trend. During the same period, however, the dockside value of blue crabs as a proportion of total Chesapeake Bay landings has risen. In 1970, the blue crab harvest was about 49 percent of the total food fish and shellfish harvest value in the Bay. In contrast by 1989, the hard blue crab harvest was about 70 percent of the total value.

Despite the apparent long-term stability in harvest levels, the decline in other fisheries has focused attention on the status of the blue crab fishery. Overharvesting, which may reduce future population levels, is a concern, as 1992 was the lowest blue crab harvest on record in Virginia in the past 30 years. As catch levels fluctuate from year to year, showing no trend in total harvest, the catch per crab gear license issued jumped sharply in the early 1980s and exhibits a slight downward trend since. This is a crude measure of fishing effort, since licenses are issued for a gear type rather than a number of gear units. There is currently no accurate measure of fishing effort in the crab pot industry. However, the decline in catch per crab gear license is often cited as evidence of falling population levels.

Also, with increased recreational use of the Bay, the recreational harvest for direct home consumption may be rising. However, there is little recreational harvest data so the extent of this harvest pressure is simply a matter of speculation.

For the Bay's watermen, the increased reliance on the blue crab as a revenue source has caused those who harvest the crabs to complain of low prices received for their product. Price trends reveal that the real (inflation adjusted) exvessel prices of blue crabs (prices received by harvesters for fish and shellfish landed at the dock) has not declined in recent years (see Figure 2), although the wide fluctuations in price in the early seventies are no longer apparent (US Department of Commerce).

Study Objectives

In 1989, in response to concerns of overharvesting and low incomes in the fishery, a Blue Crab Subcommittee of the Virginia Marine Resources Commission (VMRC) was formed. This committee consists of Virginia watermen, crab processors, and VMRC personnel. The main purpose of the committee is to discuss policy related issues and to decide how to implement measures mandated by the Chesapeake Bay Blue Crab Management Plan.

In 1989, as part of the Chesapeake Bay agreement, crab fishery management plans (FMPs) were developed. The current bi-state blue crab FMP states the following:

> The goal of this plan is to manage blue crabs in a way which conserves and protects the ecological value of the stock, and at the same time generates the greatest long term

economic and social benefits from the resource [Chesapeake Bay Executive Council, 1989]

The bi-state FMP also calls for an effort to, "investigate and promote harvesting practices which minimize waste and maximize economic return from the resource". And then, in a statement especially germane to this study, the FMP seeks to "promote studies to collect the kinds of economic, social, and fisheries data required to effectively monitor the status of the blue crab fishery" (Chesapeake Bay Executive Council, 1989).

These excerpts from the bi-state crab FMP recognize that people harvest crabs for income and for pleasure, and a plan to manage the fishery is ultimately a plan to manage people's harvest to achieve some social purpose related to these income and recreational values. The goals and motivations of these people, often income driven, must be analyzed and understood if regulatory strategies are to influence behavior of harvesters. Management questions needing attention include:

- Who are the people in the fishery?
- Where are the crabs being sold?
- What are current harvest, income, and price levels in the commercial sector?
- What are harvest levels outside of the commercial sector?
- What are the income, harvest, and effort effects of alternative management policies?

To answer questions such as these requires that catch per unit effort, costs of harvest, market distribution channels, and the exvessel price formation process be understood.

Lack of accurate data and careful economic analysis of such data is a serious problem within the industry. Landings reported to the National Marine Fisheries Service (NMFS) appear to have been underestimated in the past (Vance, 1982), and exvessel prices are gathered from large picking houses which may currently be taking less and less of the market share of blue crabs. There are little available data on costs currently faced by the watermen.

The main purpose of this study is to examine the effects of fishery management strategies on the harvest and income levels of crab potters in Virginia. This study gathered data that was used to examine the effects of alternative policies on the income of potters in Virginia. In 1991, crab pots accounted for over 70 percent of the hard and peeler crab commercial catch in Virginia. Because of this, the primary focus for this study is the hard and peeler crab harvest by pots. While hard crab catch far exceeds that of peeler crabs, the peeler crab industry in Virginia is important, as it provides close to 60 percent of the annual U.S. soft crab harvest. For this reason and because there are some harvesters who fish both hard crab and peeler crab pots, consideration will be given to the economics of the hard and peeler crab industries, and comparisons between the two will be developed.

One of the most important steps in analyzing the industry is outlining the economic and physical flows into and out of the fishery, recognizing types and amounts of inputs (or fishing effort), the harvest result and the marketing system. The combination of inputs defines fishing effort, although the primary indicator of effort for this study will be pot days fished. This report addresses the above questions and provides important and accurate data on the blue crab harvesting sector.

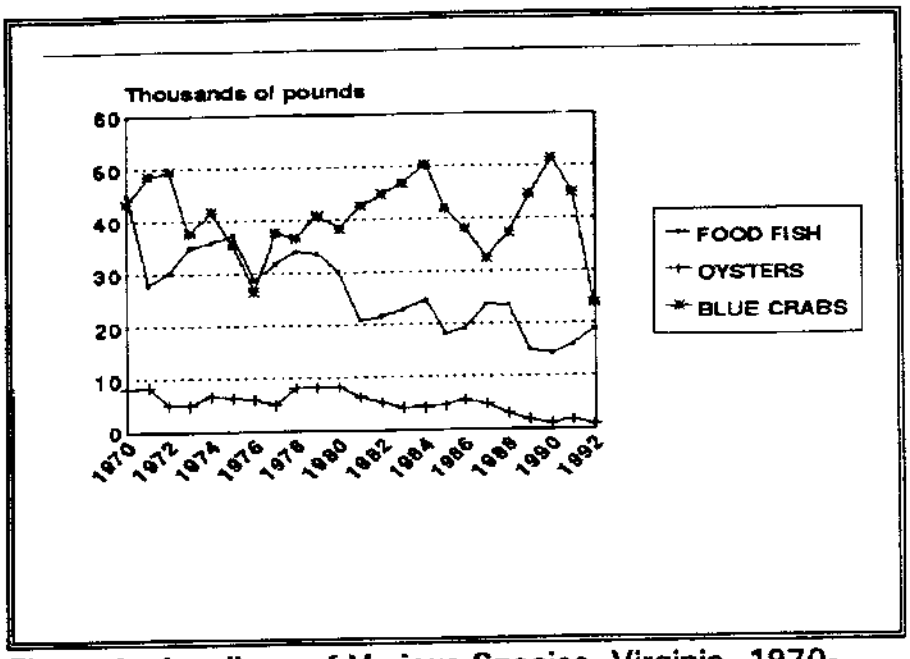

Figure 1: Landings of Various Species, Virginia, 1970-1992

Source: National Marine Fisheries Service

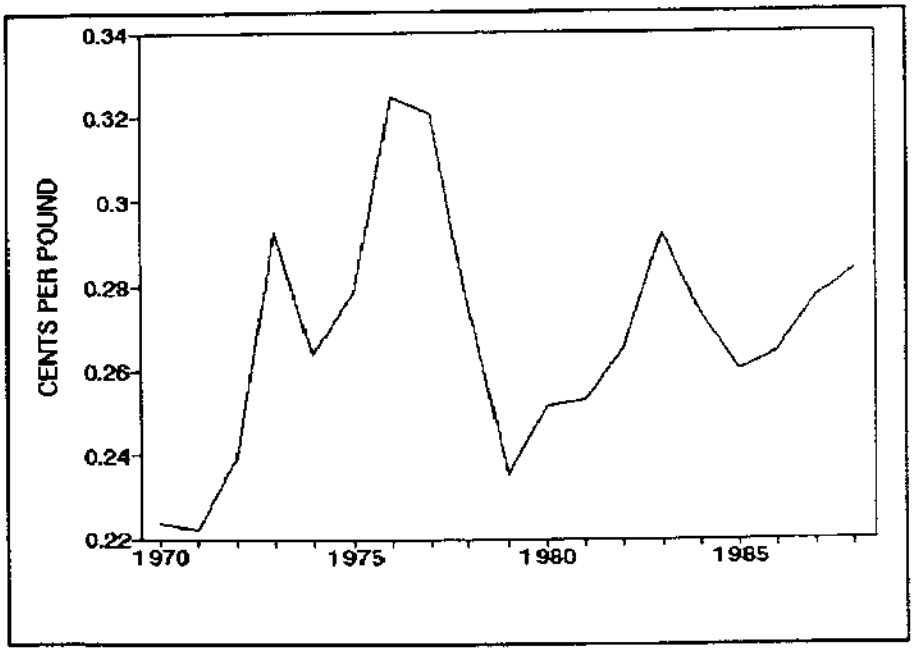

Figure 2: Exvessel Price - Hard Blue Crabs

Source: National Marine Fisheries Service

II. How Does the Fishery Operate?

Figure 3 is a representation of the flows of inputs and outputs for the blue crab pot harvesting sector. At the bottom are the variable and fixed inputs used in harvesting for both hard and soft crab operations. These inputs contribute to harvest which, in turn, move through a series of available marketing channels. The hard crab firm may sell all or part of its catch to a processing plant (where crabs are processed for picked meat), to the basket trade (people in trucks who take crabs at the dock and may sell them either to processing plants or retail them directly), retail them steamed and/or as picked meat or keep the crabs for personal use. If the hard crab harvester chooses a marketing channel other than the processing plants or basket trade buyers who come to the dock, there are additional costs including transportation, cooking, and/or picking. Also, these alternative channels are not available everywhere. While the prices the crabber receives may be higher in marketing channels other than the traditional picking houses, there must be an available sales outlet for the live crabs.

For peeler crabs, a harvester may choose to shed his own crabs which requires more inputs including a shedding system (which can be either floating in the water or a recirculating system) and labor. Peeler crabs are held in the shedding system for anywhere from a few hours to 5 or 6 days, until they shed their hard outer shell. After this, the crabs are usually frozen and shipped to a retailer. Peeler crab harvesters may also choose to sell their crabs to a shedder who then retails them. Again, if a harvester retails his own soft crabs, there must be an available sales outlet. Also, a peeler crab harvester may choose to keep part of his catch for home use.

The next sections give a brief overview of each of the steps in the harvest and marketing chain.

Biology of the Blue Crab

The blue crab is known as *Callinectes sapidus*, which translates as "savory, beautiful swimmer". It inhabits near-shore waters along the Atlantic coast from New Jersey to Florida and along the Gulf Coast to Texas. It is also found in small quantities in Europe and in larger quantities on the coast of Israel and in the Nile River Delta.

Mating of the blue crab occurs in brackish water between early May and October, but mainly in late summer, in the Chesapeake Bay. Females mate only once, while in the soft shell state, but males may mate several times. Females can have anywhere from 700,000 to 2 million eggs in one spawning. Crabs go through eight larval stages before they become a "first crab". During these larval stages, the crabs serve as food for various fish in the Bay.

Crabs grow by shedding their hard, outer shells. Small crabs shed frequently, but the time interval between sheddings increases as the crabs grow. Young crabs moult every 3 to 5 days, while older crabs may shed every 20 to 50 days. There are 25 to 27 sheddings between the first larval stage and the adult (Van Engel, 1973).

In the Chesapeake Bay, crabs become 5 inches or larger in width in 14 to 18 months, between August and November of the second summer of life. Crabs may live for more than 3 years, but few live for more than 2 years. In the Bay, crabs undergo semi-hibernation when the water temperature falls to 40 degrees F or less.

The short life span of the blue crab, coupled with its large reproductive capacity, makes it unlikely that a Schaefer stock-recruitment curve, where harvest in the period is a function, in part, of the previous year's harvest, is appropriate for the blue crab.

Instead environmental factors, such as temperature and salinity, appear to be the main determinants of stock size in any year (Chartier, 1988).

Commercial Harvest and Distribution

The blue crab is harvested in two forms. Hard crabs are taken when their exoskeleton has hardened between moultings, and are sold live, steamed, or as picked meat. Soft crabs have recently shed their exoskeleton. The marketed soft crab is often harvested as a peeler crab, a crab which is preparing to moult. Peeler crabs are kept in pounds or floats until they shed their exoskeleton, and are sold live or frozen or, if they die during moulting, are sold as fishing bait.

Hard Crab Harvest. The harvest of hard blue crabs in Virginia takes place all year long. For nine months of the year, from March to November, hard crabs are caught mainly in pots. A crab pot is a mesh wire, nearly cubical cage with two to four openings on each side, through which crabs enter, attracted by bait placed in a central compartment. Harvesters will either buy crab pots already made or they will buy the wire to make the pots themselves. A certain length of rope is attached to the pot, anywhere from 20 to 30 feet, depending on the depth of the water where the pot is set. A colored buoy, attached to top of the rope, floats on the water so that crabbers can identify and locate their pots.

At the beginning of the season, the harvester puts his pots in the water so that they sit on the bottom of the river or Bay. Pots are left in the water for the entire season and are pulled up every one or two days to empty out the crabs and rebait the pot. The most common type of bait used is fresh or frozen menhaden. Pots are replaced as they wear out and/or are cut or stolen. The average life of a crab pot is 18 months or 2 full seasons.

Crab dredges are used in Virginia to harvest crabs from December to March. Dredging consists of raking semi-dormant crabs off the bottom of the water with a metal toothed bar, connected to a mesh bag (Van Engel, 1962). The dredging of crabs is not permitted in Maryland and there has been some concern, especially among Virginia crab potters, that dredging, which does not allow for any closed season on crabs, may be responsible for reducing blue crab stocks to dangerously low levels. Potters also dislike dredging because they feel it holds the price of crabs down in the spring and fall, as there is a supply going to the processors all year round.

Peeler Crab Harvest. Peeler crabs and soft crabs are generally harvested between April and September, due mainly to the fact that is difficult to attract moulting crabs during their winter hibernation. The main gear types used to catch peeler and soft crabs are peeler pots, crab scrapes, and pound nets. Peeler pots are similar to hard crab pots, but they are baited with a male crab, called a Jimmy to attract female peeler crabs who are ready to moult. Harvested peeler crabs are usually in one of three shedding states - less than 1 day from shedding, 1 to 2 days from shedding, and 3 to 4 days from shedding. The color of the claw of a peeler crab indicates which stage of shedding it has entered.

Crab scrapes are toothless dredges used to gather peeler and soft crabs from the protective eelgrass where they go to moult. Peeler pound nets stretch out into the water from the shore and lead crabs to a trap from which they cannot escape.

Distribution of the Catch. After the crabs are harvested, they can be sold through many channels. Crabbers may sell all or part of their hard crab catch to picking houses, where the crabs are processed into meat. They may sell their peeler crabs to shedders. They may also choose to sell all or part of their catch to the "basket trade", which consists of wholesalers or retailers who buy

crabs at the dock. As part of the "basket trade" crabbers may also perform value-added activities, including shedding their own crabs, steaming their hard crabs, or retailing their live crabs directly. Some crabbers even choose to fly their soft crabs directly to Northern markets (Wesson, conversation). Large crabs are usually sold as whole crabs in the basket trade, but the smaller crabs (with less meat) usually go to the picking houses to be processed.

Hard Blue Crab Processing Sector

While many marketing channels exist for large hard crabs, processors take most of the smaller hard crabs, which are not usually sold live or steamed. Instead the small ("picking") crabs go to picking houses where they are steamed and the meat is picked from the shells. Processed products include: fresh and pasteurized crab meat, frozen and canned specialty products, and hermetically sealed canned crab meat (Dressel and Whitaker, 1982).

The average meat yield of hard blue crabs in the Chesapeake Bay region is between 8 and 12 percent, meaning that 100 pounds of live crabs yield 8 to 12 pounds of crab meat, in various grades. Although it varies depending on regional customs and state laws, the technology used in processing blue crabs has changed little since fresh crabmeat was first marketed in the late 1800s. Hand-picked crabmeat still constitutes the major product from the crab plants (Hong, 1990).

There is some mechanization within the industry, mostly in the larger plants. The Harris process is used to remove claw meat. In this process, claws are put through a hammer mill type machine that breaks the claws into many small pieces. The meat is separated from the shells by a brine floatation process with the meat floating to the top and the shells sinking to the bottom. The meat is sprayed with fresh water and the water is removed by a metal squeezer. A second picking machine is the Quik-Pik, which removes meat from the main body of the crab by high speed vibration (Hong, 1990). These mechanization techniques are not widely used in the processing industry, not only because of their high startup costs, but also because the meat produced by these machines is of lower value than hand-picked meat.

Recreational Harvest

The size of the blue crab recreational fishery in Virginia is unknown, but it is thought to be quite large. In addition to those who fish recreationally with only 1 or 2 pots per person or by hand lines with dip nets (which does not require a license), a fairly substantial portion of the license-holding population could be considered recreational or non-commercial, in that they do not derive any part of their income from potting. Because this catch does not move through any marketing channels, it goes unreported. Concerns about this sector have come from both commercial fishermen and Chesapeake Bay fishery managers. The watermen are concerned that recreational fishers are claiming too large a share of the harvest and that some of them may be selling part of their catch, which gluts the market and holds down exvessel prices. Chesapeake Bay fishery managers are concerned about the lack of information on the recreational sector and the inability, therefore, to establish whether or not it has an impact on blue crab population levels. A further exploration of the impact and characteristics of the noncommercial sector will be presented later in this report.

Current Regulations

While new regulations are being considered for the industry, there already exist some laws in Virginia that govern the fishery. Each person wishing to catch crabs commercially (more than 2 pots per person) must purchase a gear license. For anyone fishing from 3 to 5 pots, there is a recreational license which

can be purchased. Anyone fishing more than 5 pots must purchase a commercial license. In January 1994, the Virginia Marine Resource Commission (VMRC) will begin issuing separate licenses for hard crab pots and peeler pots. There is currently no limit on the number of gear licenses that can be sold, or on the number of gear units that can be employed once a commercial license is purchased. In 1990, 2550 crab pot licenses were sold.

Hard crabbing is prohibited on Sundays, and potting is not allowed from December 15 to January 31. Crab dredging is only permitted from December 1 to March 31 and is prohibited on Saturdays and Sundays and between sunset and sunrise on all days.

The minimum size limit for male hard crabs and sexually immature female hard crabs is 5 inches. There are no minimum size limits for peelers, soft crabs, or adult female hard crabs (sooks). Some watermen believe that enforcement of these size limits is not effective because fishery inspector checks are sporadic and because culling rings, which release small crabs from pots, are not mandatory in Virginia.

The crab dredge fishery has a 75 bushel limit of crabs per day per vessel. In the pot fishery, catch is restricted to 51 bushels or 17 barrels per vessel per day from March 15 to May 31. There are also area restrictions. Dredges are not allowed in rivers, estuaries, inlets, or creeks. There is a Crab Sanctuary Area in the lower Bay, where crabs cannot be taken from June 1 to September 15. Hard crabs may not be taken at any time from the Tangier Island Crab Scrape Sanctuary (VMRC circular, 1992).

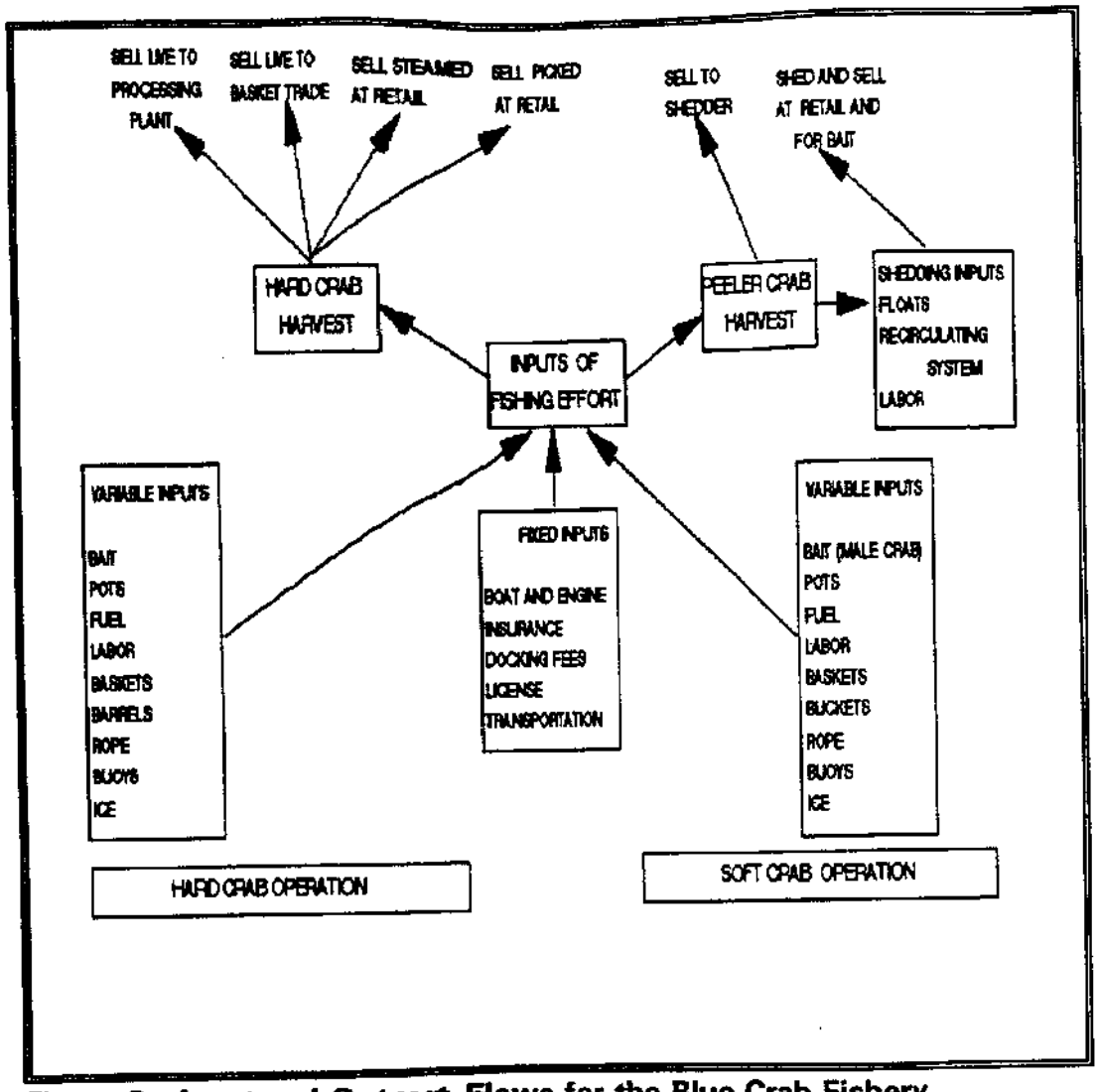

Figure 3: Input and Output Flows for the Blue Crab Fishery

III. Study Procedures

In order to characterize the fishery, a series of steps were taken to profile the Virginia blue crab pot fishery for 1992. The main source of data for this profile was a series of monthly surveys of individual license holders, conducted from March to November of 1992.[1] In order to make the survey as efficient and useful as possible, a series of interviews were conducted with people involved in the fishery. A rough draft of the survey instrument was sent to three watermen in Virginia, who included a peeler crabber and two hard crab potters. All of these watermen were members of the VMRC Blue Crab Subcommittee. These watermen were personally interviewed and gave their comments on both the merits and problems of the survey instrument and on characteristics of the industry. The survey was also sent to personnel at VMRC and the Virginia Institute of Marine Science (VIMS) who, because they had both previously conducted surveys of watermen, provided valuable insights on survey design and implementation.

In order to better understand the harvesting sector, two watermen were accompanied on their daily crabbing runs - a peeler crab run on the York River and a hard crab run in the Rappahanock River and Chesapeake Bay. These trips provided insights on the everyday work of watermen -from how the boats are loaded in the morning to how the catch is marketed in the afternoon.

On the processing side, an interview was conducted with a large picking house company in Virginia. This interview provided information on how processors operate, the competition they face, and how the prices they offer to watermen are formed. Another interview was conducted with a soft crab harvester and wholesaler in Virginia, which gave some insights into soft crab price determination.

The basic objective of the survey instrument in this study was to provide primary data on inputs and outputs from the crab pot sector of Virginia. The survey was designed to gather data to be used in estimating production, cost, and net return functions for the 1992 season. Because both input and harvest levels vary throughout the year, the survey was conducted on a monthly basis from March to November. The potting season generally begins in mid-March and ends in mid-November, but surveys for March and November were combined with those for April and October, respectively, totaling 7 separate survey instruments for the season.

A monthly survey was also chosen to avoid recall problems that might result from one mailing at the end of a season and also because watermen were required to provide catch data for only one month. Few questions on costs were asked, except for the fixed costs that the crabber pays annually. This helped to prevent non-responses as the questions did not require the watermen to provide all the financial details of their operation. Costs for variable inputs were obtained in a telephone survey of selected crabbers (those who, through their comments on the survey, expressed concern for the fishery and a willingness to provide additional information).

The survey was divided into two parts (See Appendix E). Part I contained questions for all of the respondents to answer. These included attitude questions about fisheries policy, general characteristics of the crabber, and fixed costs and inputs. Part II was to be answered by those who crab potted during the month they received a survey. This section included a monthly calendar, on which respondents were asked to fill in the number of bushels of peeler and/or hard crabs that they caught each day. The rest of the section asked questions about variable inputs (bait, pots, labor, etc.) and marketing channels. The

survey ended with a section for additional comments by the crabber. A full discussion of sampling procedures and response rates is given in Appendix D.

1. Before the extensive profile of the fishery began in 1992, a short survey was done in the summer of 1991. This survey was designed to determine the characteristics of those who enter and exit the blue crab pot fishery and if these characteristics differ from those who remain in the fishery. This survey was 3 pages long and a copy is shown in Appendix E as Survey 1.

IV. Who are the License Holders in the Crab Pot Fishery?

There are few available data on the differences among crab pot license holders and on the characteristics of their operations. No information on the number of gear units or number of days fished or vessel characteristics is gathered when licenses are sold. This study provides much of this previously unknown information.

Table 1 presents firm characteristics for the entire fishery, showing the range of license holders and the average and median license holders. One important feature to note is that this is an extremely diverse fishery, with vessel ages ranging from new to over 60 years old and with number of pots fished ranging from 1 to 600. The median values for pots fished and days fished per season are lower than the average values, indicating that the majority of license holders tend to be smaller operators. Also, the average boat length is 24 feet, demonstrating the small-scale of most license holders. There is a relatively small group (about 16 percent of license holders) who are large-scale operators, but the general indications are that this is not a capital intensive fishery, with much high-tech equipment and many big operators.

The crab pot license-holders were divided into three general categories:

Maryland Commercial

Those who live in Maryland but hold a Virginia crab pot license

3.4 Percent

Virginia Commercial

Those who live in Virginia and derive any part of their income from potting

64 Percent

Va. Non-Commercial

Those who live in Virginia and derive none of their income from potting

32.6 Percent

Maryland vs. Virginia Commercial Crabbers

Approximately three percent of the license holders were Maryland residents who crab potted in Virginia waters in 1992. Of these all were considered commercial. Table 2 shows a comparison between the Maryland and Virginia commercial crab pot sectors. The Maryland crabbers fish more peeler and hard crab pots per day than those in Virginia. Maryland crabbers have larger vessels and have more experience even though they are younger than their Virginia counterparts. They also fish more months of the year, especially in April and November. Maryland crabbers derive more of their income from potting than commercial potters in Virginia, indicating that they rely on crabbing for most of their income.

Summary

- A small percent of license holders are from Maryland, but they are large operators
- One-third of the license holders are non-commercial, but they tend to fish more than 5 pots
- The majority of crab potters fish less than 200 pots per day
- The largest firms are on the Eastern Shore
- Those who hard crab pot only are the largest segment of license holders
- People who buy their crab pot licenses every year tend to be larger operators than those who get in and out of the fishery

Marketing Channels: A Summary

- About 8 percent of license holder catch is for personal use
- About 60 percent of hard crabs are sold to picking houses
- About one-third of peeler crabs are

in Virginia. Approximately 60 percent of the hard crabs are going to a picking house, while the remaining 40 percent are going to a non-traditional marketing channel, with 2 percent kept for personal use. For peeler crabs, a higher percent are kept for home use, just over 6 percent. About half of peeler crabs are sold to a shedder, with about one-third being shed by the harvester and sold to a retail market.

[1] The entry/exit respondents were classified by size, region, and type of firm. The only difference in this classification was that commercial and non-commercial crabbers were defined by number of pot days fished rather than percent of income from crabbing.

Table 1: Firm Characteristics

Variable:	Min.	Max.	Mean	Median
Hard pots fished	3	600	127	100
Peeler pots fished	1	500	135	100
Hard pot days per season	4	235	117	109
Peeler pot days per season	13	183	73	61
Length of crabbing vessel (feet)	12	50	24	20
Age of crabbing vessel (years)	1	66	15	12
Age of engine (years)	.5	83	8	5
Percent income from potting	0	100	37	25
Percent income from other fishing	0	100	12	0

Table 2: Maryland and Virginia Commercial Crab Pot Firms

	Maryland	Virginia
Average hard crab pots fished	360	169
Average peeler pots fished	206	146
Days hard potted per season	140	140
Days peeler potted per season	98	74
Length of crabbing vessel	38	27
Age of crabber	46	50
Years of crabbing experience	29	22
Percent income from potting	86	54
Months Fished: (Percent)		
March	40	32
April	80	66
July	87	86
October	67	65
November	53	44

Table 3: Non-Commercial Virginia Crabbers

	Non-Commercial
Average hard crab pots fished	16
Average peeler pots fished	10
Days hard potted per season	63
Days peeler potted per season	64
Age of crabber	59
Years of crabbing experience	20
From Region 1	8%
From Region 2	71%
From Region 3	21%
Months Fished: (percent)	
March	3
April	19
July	94
October	35
November	6

Table 4: Virginia Commercial Sector - Distribution of Pots Fished

Number of pots:	% of Peeler Potters	% of Hard Crab Potters
1-99 pots per day	36	26
100-199 pots per day	25	36
200-299 pots per day	30	18
300-399 pots per day	6	14
400 or more pots per day	3	6

Table 5: Terms Used for Classifying Crab Pot License Holders

Large operators	fish more than 300 pots a day
Medium operators	fish between 100 and 300 pots a day
Small operators	fish less than 100 pots a day
Region 1	Eastern Shore of Virginia - counties of Accomac and Northampton
Region 2	Counties of Eastern Virginia north of York River - counties of Westmoreland, Northumberland, Richmond, King George, Stafford, Prince William, Loudan, Spotsylvania, Orange, Caroline, Essex, Lancaster, King and Queen, King William, New Kent, Hanover, Louisa, Goochland, Henrico, Gloucester, Middlesex, Mathews, Fairfax, and city of Arlington
Region 3	Counties of Eastern Virginia south of York River - counties of York, Isle of Wight, Southampton, Dinwiddie, Prince George, Surry, James City, Charles City, Chesterfield, and the cities of Chesapeake, Virginia Beach, Norfolk, Hampton, Newport News, Richmond, Suffolk, and Portsmouth

Table 6: Virginia Commercial Crabbing Firms, by Size

	Small	Medium	Large
Average hard crab pots fished	47	158	302
Average peeler pots fished	31	119	241
Days hard potted per season	119	149	147
Days peeler potted per season	61	71	87
Length of crabbing vessel	19	27	33
Age of crabber	58	50	42
Years of crabbing experience	20	24	22
Percent income from potting	25	59	70
From Region 1	6 %	23 %	55 %
From Region 2	63 %	58 %	36 %
From Region 3	31 %	19 %	9 %
Months Fished: (percent)			
March	21	32	45
April	49	62	95
July	92	87	82
October	52	65	79
November	20	43	66

Table 7: Virginia Commercial Crabbers by Region

	Region 1	Region 2	Region 3
Average hard crab pots fished	238	155	145
Average peeler pots fished	216	80	59
Days hard potted per season	125	144	148
Days peeler potted per season	83	70	50
Length of crabbing vessel	28	26	26
Age of crabber	47	50	51
Years of crabbing experience	23	23	20
Percent income from potting	56	55	46
Months Fished: (percent)			
March	36	29	49
April	70	61	76
July	69	92	92
October	53	70	70
November	41	43	55

Table 8: Virginia Commercial Crabbers by Firm Type

	Hard/Peeler	Hard Only	Peeler Only
Average hard crab pots fished	159	176	n/a
Average peeler pots fished	134	n/a	179
Days hard potted per season	118	148	n/a
Days peeler potted per season	68	n/a	91
Length of crabbing vessel	25	28	21
Age of crabber	45	50	52
Years of crabbing experience	19	23	25
Percent income from potting	52	55	48
From Region 1	64 %	11 %	25 %
From Region 2	17 %	68 %	5 %
From Region 3	19 %	17 %	64 %
Months Fished: (percent)			
March	40	35	7
April	76	70	24
July	76	92	62
October	61	75	13
November	45	51	3

Table 9: Transient and Permanent Crab Potters

	Transient	Permanent
Average hard crab pots fished	88	125
Average peeler pots fished	109	139
Days hard potted per season	88	125
Days peeler potted per season	91	114
Length of crabbing vessel	21	23
Age of crabber	47	52
Years of crabbing experience	15	22
No non-fishing income	28	38
Months Fished: (percent)		
March	13	25
April	33	50
July	72	77
October	24	40
November	11	24

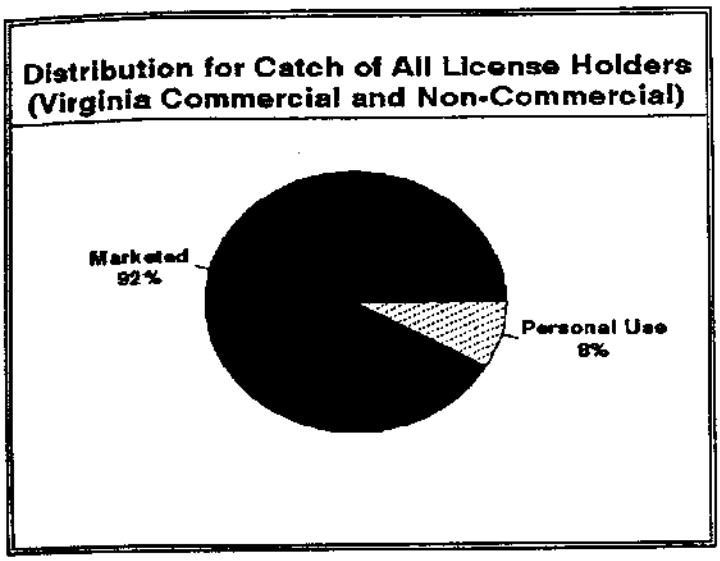

Figure 4: Total License-Holder Catch Distribution

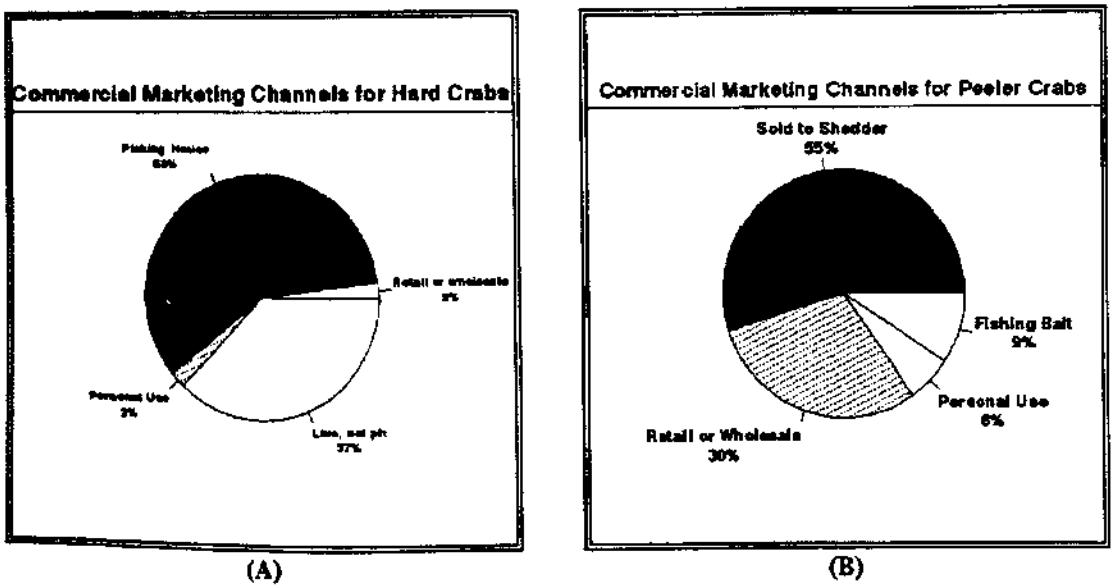

Figure 5: Commercial Marketing Channels

V. Economic and Biological Theory of the Fishery

Fishery analyses contain both biological and economic components, encompassing issues such as population dynamics and propery rights. This section examines some of the underlying biological and economic concepts used to develop harvest, price, and income estimates for the fishery.

Bio-Economic Relationships

Effort in the fishery is defined in two ways. Nominal fishing effort refers to the volume of resources devoted to fishing, quantified either as monetary or physical units. Effective fishing effort is used by biologists to refer to fishing mortality, usually measured as the biomass of fish extracted by fishing, expressed as a proportion of the mean population (Cunningham, 1985). In this study, all references to effort will be to nominal fishing effort, which will mainly be defined as pot days fished, but may also include other variables such as bait and labor. Pot days fished is the number of pots fished each day multiplied by the number of days fished.

Production, in fisheries, is a combination of biological and economic factors. Fisheries are renewable resources, meaning that the stock size may be increased as well as decreased by general environmental factors and harvest levels (Pearce and Turner, 1991). In particular, harvest in time period t influences harvest in time period t+1. Design of management policies, therefore, requires a basic understanding of the population dynamics of the fishery.

Many economic analyses of fisheries begin with the assumption that the population dynamics of a fish species are characterized by a Schaefer stock-recruitment curve. This biological theory assumes that the growth of the fish stock measured in weight is a function of its size in weight. In the long run, this relationship allows for a constant maximum sustainable yield (MSY), which is the highest level of harvest that can be taken each period without negatively affecting the size of the population.

One of the major assumptions of the model is that harvest in one period affects harvest in the next period. This model may be appropriate in a fishery where environmental changes do not have a large influence on the fish population. The blue crab fishery, however, is highly influenced by its marine environment. The population is usually dependent upon certain ecological conditions during critical phases of its life cycle and bears little relation to the population size of the previous generation.

In 1985, Willard Van Engel, professor Emeritus at VIMS, summed up the current thought on blue crab dynamics:

> There is no evidence of any long-term change in the number of blue crabs in the Bay. Although the commercial catch varies from season to season and year to year, these variations result from short-term changes in the quality of the environment. Water, temperature, salinity, dissolved oxygen, the quality and quantity of food affect reproduction, growth, and the rate of survival of every stage in the crab's development. [VIMS bulletin, 1985]

A 1992 publication from the Chesapeake Bay Program reported that the only attempt made to directly assess the size of the female spawning stock of blue crabs demonstrated a year-to-year variability of nearly 80 percent (Rickhus et al., 1992). This emphasizes the importance of accurately modeling the population dynamics of the blue crab. Attempts at this have been made. Some authors have found a spawner/recruit model (like the Schaefer model) to be inappropriate because of the overwhelming importance of

the physical environment in determining recruitment success for the blue crab (Applegate as cited in Rickhus, 1992).

Some models based on the Schaefer analysis have suggested the MSY for blue crabs in the Chesapeake Bay to be between 69 and 77 million pounds. Landings in the Bay in the 1980s were consistently larger than these numbers, indicating either that the stock is ready to collapse or that these MSY estimates are inappropriate for the fishery. Rickhus et al. conclude that more work is needed to obtain more accurate stock assessments of the blue crab population.

The early 1992 season was characterized by low rates of harvest and small crabs. Some concerns were raised by watermen and Chesapeake Bay managers about harvest pressures on the population. VIMS scientists have cited a drop in the natural cycle of the crab larvae, along with weather patterns and currents at the mouth of the Bay, as the key factors in the low catches. There is still some concern, however, that increased harvesting pressure in recent years is responsible for the decreased catch.

For this study, the blue crab fishery will be assumed to be a density independent stock, meaning that growth levels are not affected by harvest levels in previous time periods. This assumption is consistent with most of the scientific literature, which stresses environmental factors over human factors in blue crab population determination. It also is an acceptable assumption for the single year focus of this study. Harvest, therefore, will become a direct function of effort and the population level in any given year.

Graphically, Figure 6 shows effort-yield functions for different stock sizes, where CC represents the maximum carrying capacity of the environment and 3 is the largest possible stock size (Cunningham, 1985). The possibility of diminishing returns to effort is represented by the concave shape of the effort-yield function.

Determination of Economic Returns in the Fishery

The blue crab fishery is a common property resource, one that is not exclusively controlled by a single agent or source (Tietenberg, 1992). The blue crab fishery is not completely an open access system, where no one owns the resource and access is open to all. While no one owns the blue crab resource, access is limited by the laws that govern the fishery and by the skills of the watermen. Crabbers must be licensed by the state, there is a closed season on crab potting, and there are catch limits at certain times of the year to limit effort.

Total costs of effort, for the blue crab fishery, will be increasing as effort increases due to the differences in skills of the watermen. Since there are various degrees of skill, as less skilled labor enters the fishery, the cost of supplying extra effort increases because more non-labor inputs must be used with each unit of labor (Anderson, 1986). Also costs can be increasing because the opportunity cost of crabbing labor is rising.

Figure 7 is a general representation of industry harvest equilibrium for Virginia's blue crab fishery. In Panel A, ES is the supply response for effort function, which is upward sloping, indicating that effort enters the fishery in response to expectations that the return to effort will equal or exceed the cost of effort. MRP_e and ARP_e are, respectively, the marginal and average revenue products of effort, which are the marginal and average products of effort times the dockside price of blue crabs. These curves are negatively sloped, suggesting that the marginal and average products of effort decline with increasing levels of effort.

In a sole owner fishery, equilibrium effort occurs where MRP_e = ES, point E_{so}. At this point the owner is deriving rent to the ownership of the rights to fish (resource rent) of ABFH. He is paying out rent of $FGHE_{so}$ to those who work in the fishery.

In an open access fishery the crab stocks are unowned and there is unrestricted entry of fishing effort. Harvest costs will vary across fishermen using identical levels of effort and all of the resource rent will be dissipated to the point where ARP_e = ES, point E_{oa}. At this point factor rent is GCE and this rent accrues to the more highly skilled fishermen who have low cost curves. The rent derived under an open access system (GCE) is less than the rent derived under the sole owner regime (ABFH + GFH), which indicates that financial returns to the industry are lower in an open access system.

In Panel B of Figure 7 the total product of effort (TRP_e) is shown. Harvest increases at a decreasing rate with effort. The sole owner effort level results in a harvest level of H_{so}, while the open access effort level results in a higher harvest level of H_{oa}. Panel C is an inverse demand function, suggesting that increases in harvest levels will reduce exvessel prices. The sole owner harvest level results in price P_{so} which is higher than P_{oa}, the price resulting from the open access harvest level. The main reason prices are lower in an open access system is the higher harvest levels caused by the additional effort of the marginal firms who come into the fishery when access is not limited. These marginal firms, with higher cost curves than others in the fishery, bring in additional harvest which depresses prices, and therefore income, for the entire fishery. The average firm, therefore, is worse off under open access than under a sole owner regime.

Open access systems, therefore, tend to result in higher effort and harvest levels and lower price levels than sole owner regimes. The objectives of many fishery management policies are to keep effort and/or harvest levels from being too high and endangering the fish stock. As a consequence, restricting effort may raise industry and firm level incomes. These types of policies will also affect the incomes of the people in the fishery. The next sections outline the determination of harvest, price, and income levels for the 1992 blue crab pot fishery in Virginia.

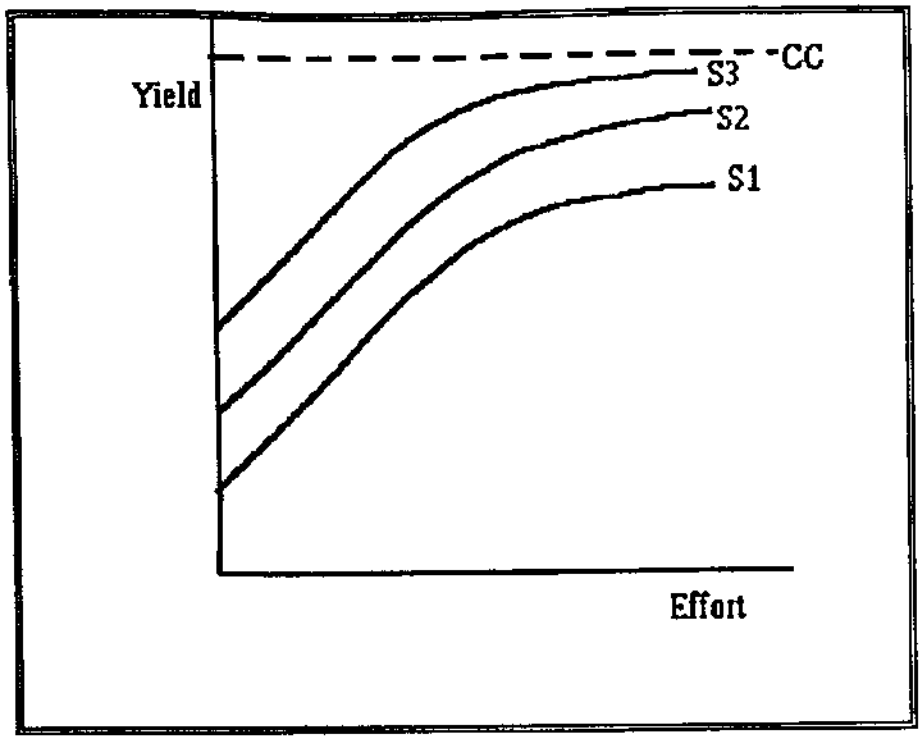

Figure 6: Effort-Yield Functions

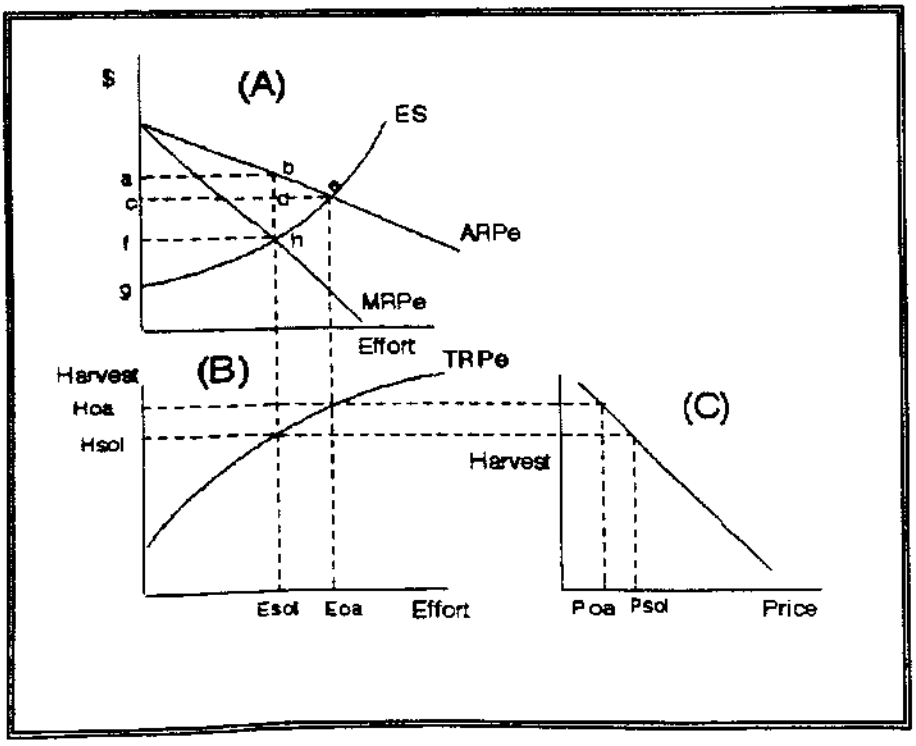

Figure 7: Sole Owner and Open Access Equilibriums

VI. What were 1992 Harvest and Price Levels in the Fishery?

1992 Harvest Levels

The level of the blue crab population is one factor which will influence the amount of crabs caught by the individual firm. This study, however, is for a single year, when effort is applied to a fixed population level, which need not be known. Therefore, in the harvest equations, there is no variable for stock size, although seasonal shifters will account for variations in stock size over a season.

Harvest equations were modeled using monthly data obtained from the surveys, with the number of pot days fished in the month hypothesized to be the main factor influencing harvest levels for an individual firm. Other variables that were hypothesized to have influence included vessel length, years of crabbing experience, crabbing region, and season of the year (see Appendix A for a full explanation and presentation of the harvest equations).

Figure 8 shows the procedures used to obtain total industry harvest levels for both hard and peeler crabs. A monthly harvest equation was estimated from the survey data and this equation predicted monthly harvest levels for each individual firm. These harvest levels were summed over all months fished to obtain an annual harvest level for each firm. These annual harvest levels were summed over all firms and aggregated up to encompass all crab pot license holders.

Sectoral Harvest Levels. For hard crabs, monthly harvest was a function of pot days fished, length of crabbing vessel, and season of the year. For peeler crabs, monthly harvest was a function of pot days fished, years of crabbing experience, and crabbing region. Annual harvest levels were estimated for four sectors of Virginia's blue crab fishery. These sectors were:

1. **Virginia Commercial Potters**
2. **Marylanders who Pot in Virginia Waters**
3. **Virginia Non-Commercial Potters (with License)**
4. **Virginia Recreational Potters (no License)**

Table 10 gives the blue crab harvest levels for each of these sectors, along with their 95 percent confidence intervals. The aggregation techniques given in Figure 5 were used to obtain the blue crab harvest levels for the Virginia and Maryland commercial sectors and the Virginia non-commercial sector. The harvest estimates for the recreational sector were based on a report published by the US Department of Commerce in 1985 on recreational shellfishing in the United States. Using that report's estimates of the number of annual recreational shellfishing days in Virginia and the number of recreational shellfishers, and assuming that recreational fishers catch 1/4 of a bushel of hard crabs a day, the recreational catch in Virginia was estimated to be approximately 16 percent of the commercial catch.

These numbers show that the commercial harvest is only 84.5 percent of the total harvest of blue crabs in Virginia. This result demonstrates that harvest levels, which are usually reported only as commercial landings, may be significantly underestimated, and may not be a true indicator of the total output of the blue crab fishery.

Determination of Exvessel Prices

Because the marketing channel analysis showed that much of the blue crab catch in Virginia goes to non-traditional outlets where the price received may be considerably higher than in traditional channels, a two-step process was used to obtain 1992 monthly exvessel price estimates for both hard and peeler crabs. This process allowed for higher prices for a portion of each waterman's catch.

Hard Crab Prices. For hard crabs, the first step was to build a predictive econometric model, based on historical data. Monthly hard crab exvessel prices were a function of monthly landings, monthly wholesale price, and month of the year (See Appendix A for a complete description and explanation of this model).

The historical price data that was used to build this model was gathered mainly from large picking houses and so this model only predicts the price the waterman will receive at the picking house for his crabs. The data in Figure 5 suggested that exvessel prices, which are currently reported as averages from the large picking houses, may not accurately represent the price that the waterman receives. Anecdotal data suggests that while picking house prices may correctly represent the prices crabbers receive for their smaller (#2) crabs, the prices for the larger (#1) crabs appears to be two to three higher than the prices of the #2 crabs. #1 crabs comprise approximately one-third of a crab potter's daily catch. However, there are no data on prices in alternative marketing channels nor any time series on the percent of catch going to each marketing channel.

A telephone survey of crabbers in early 1993 revealed that, on average, crabbers sell one-third of their catch to a retail or wholesale market where the price they receive is 2 to 3 times higher than the picking house price. Therefore, a two-price model was used to predict the average price the crabber receives for his catch. The picking house price, given by the estimated econometric equation, was paid for two-thirds of the crabber's catch. The other one-third of the crabber's catch was assumed to bring a price 2.5 times higher than the picking house price. The overall monthly exvessel price was, therefore, 1.5 times higher than the picking house price.

The monthly prices estimated by this method are given in Table 11. Prices are highest in the summer months, when demand for crab meat is at its highest. Prices are lowest in the fall, when stocks of blue crabs are high and demand is beginning to lessen.

Peeler Crab Prices. Soft crab exvessel price and landings data were obtained from the National Marine Fisheries Service. Soft crab wholesale prices were obtained from Urner-Barry, a private marketing company in New Jersey. Initial attempts at modeling Virginia soft crab exvessel prices as a function of Virginia landings, wholesale soft crab prices, and season of the year demonstrated no significant relationship among these variables. Talks with soft crab harvesters, processors, and wholesalers revealed that because soft crabs are often shipped to Northern markets for wholesaling and can often be kept frozen for months, price discovery is often difficult. Another important factor in exvessel price formation is that Virginia has a much lower share of the national soft crab market today than it did fifteen years ago. Currently Virginia provides about 60 percent of the national soft crab harvest, compared with almost 90 percent fifteen years ago (Whittaker, conversation). This means that Virginia soft crab exvessel prices are dictated more by national landings than by Virginia landings.

Consequently, monthly exvessel peeler crab prices were not modelled, but rather were taken from VMRC estimates for 1992. To account for higher prices in alternative marketing channels, the published price series was multiplied by 1.5. Table 11 summarizes the monthly 1992 estimates of exvessel prices for peeler crabs. Prices are lowest in April, when there are wide fluctuations in day to day

prices offered. Exvessel prices tend to settle in May and remain fairly constant for the remainder of the season.

Comparison to Published Harvest and Price Levels

One of the main objectives of this study was to gather accurate data on the fishery. This included both data which were currently unavailable, such as characteristics of the license holders and the marketing channels used for hard and peeler crabs, and data which are currently collected, such as harvest and price levels, which may not be accurately reported.

The 1992 method for gathering published harvest and price data for Virginia's blue crab fishery was a voluntary reporting system, whereby the Virginia Marine Resources Commission collected data from those watermen and crab buyers who were willing to report on harvest and prices. One official at VMRC conceded that, through this system, only about 60 to 65 percent of the harvest was being captured (Ner, 1993). In 1982, Vance concluded, through evidence of other surveys and calculations of net returns in the fishery, that harvest levels for Virginia's blue crab fishery were underreported by one-half (Vance, 1982).

Table 12 presents the data on harvest and prices estimated from this study and the data collected by VMRC. The report harvest in table 12 from this study does not include the harvest by Maryland crabbers in Virginia, as these numbers are not counted by VMRC. The published data's hard crab catch is about 40 percent of the catch estimated in this study, while the peeler crab catch is only about 30 percent of the catch estimated in this study. Hard crab and peeler crab prices are significantly higher in this study, mainly due to the use of the two-price model which accounts for alternative marketing channel prices.

Table 10: Harvest Estimates by Sector

Sector:	Lower Limit	Upper Limit	Average
Maryland	4,952,470	6,205,270	5,578,870
Va. Commercial	44,216,705	66,025,613	55,121,159
Va. Non-Commercial	849,019	2,018,011	1,433,515
Va. Recreational	3,124,620	16,538,804	9,786,712
Totals:	53,142,814	90,787,698	71,920,256

Table 11: Exvessel Prices Per Pound

	Hard	Peeler
March	.51	N/A
April	.62	1.78
May	.77	2.91
June	.74	2.76
July	.71	2.76
August	.71	2.79
September	.48	2.70
October	.42	N/A
November	.55	N/A

Table 12: Published Harvest and Price Data

	This Study	Published Data*
Hard Crab Commercial Harvest	53,201,713	19,712,233
Peeler Crab Commercial Harvest	1,919,446	518,770
Hard Crab Exvessel Price Per Pound	.61	.41
Peeler Crab Exvessel Price Per Pound	2.62	1.73

* Source: Virginia Marine Resources Commission

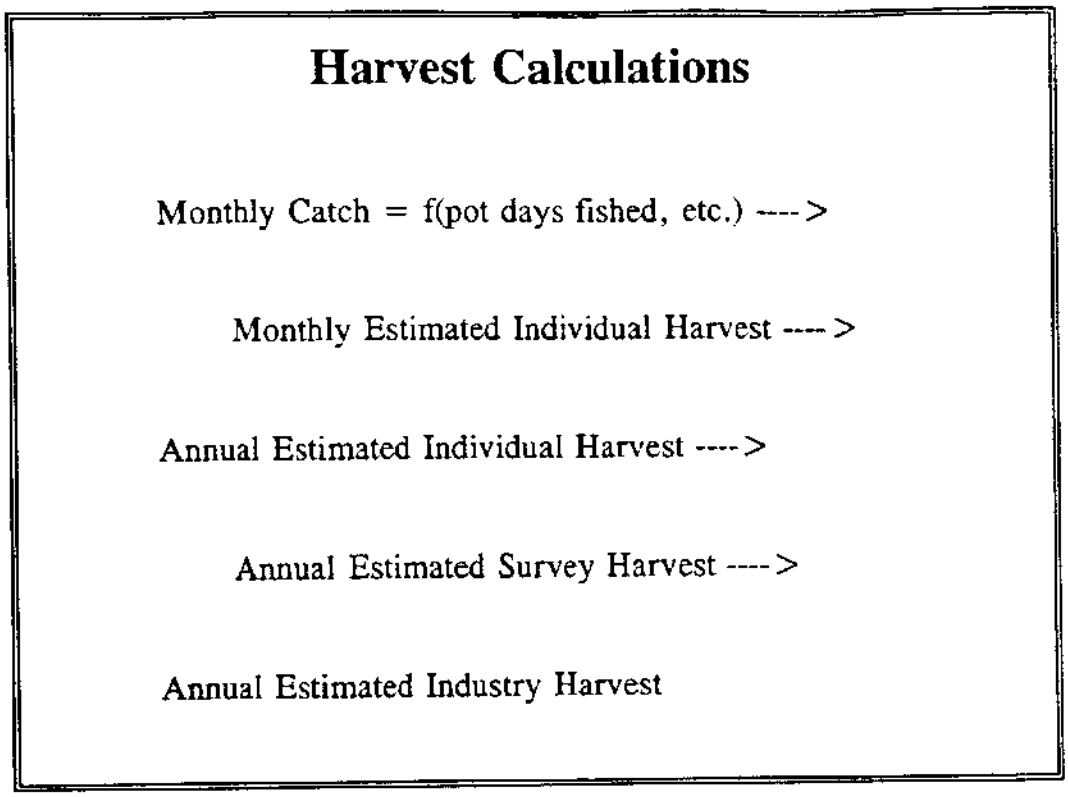

Figure 8: Harvest Aggregation Procedures

VII. What were 1992 Income Levels in the Fishery?

Figure 9 shows the flow of costs and revenues that contribute to net income for the individual crab potting firm and the crab potting industry as a whole. Exvessel price is exogenously determined for the individual firm, but at the industry level, total harvest will affect price determination. Total revenue is equal to exvessel price multiplied by the amount of crabs harvested, which will be a function of fishing effort for the individual firm, but at the industry level will also be affected by the blue crab population size.

An important consideration in this fishery is that these variable inputs are not highly substitutable within an individual firm, but can be substituted (to a certain degree) within the industry. This implies that some of the inputs must be used in a fixed proportion, ie., if a person decides to fish one more pot then they must use some amount of additional labor to fish the pot, a fixed amount of additional bait to put in the pot, and some amount of additional fuel to get their boat to the pot.

Fishing a pot more than once a day will not generally produce more crabs than fishing it only once a day. The use of more bait per pot will also not significantly increase returns to effort. There is some possibility for substitution between labor and pots in that a person may choose to fish less pots and extend the number of days on which he pots. This possibility is limited, however, not only by the closed season on potting, but also by the seasonal nature of crab landings. Therefore an individual waterman cannot usually substitute inputs on a large scale, but must either contract or expand the size of his operation, which is best represented by pot days fished.

The substitution of pots for labor is more possible within the industry as a whole. For example, if the labor supply is limited in the fishery by regulation, the people who remain may fish more pots (ie, expand the size of their operation). This same effect will occur if the number of pots per person is limited. More people will enter the fishery if they find the opportunity cost of fishing to be acceptable. This idea will be explored further as the dynamic implications of the simulation model are discussed.

Total costs are the sum of fixed costs and variable costs. Fixed costs are those which the firm faces whether or not it crabs on a given day. Variable costs are the costs of fishing inputs such as pots, bait, fuel, and labor. Table 13 is a list of the costs used for this study, showing the price per unit for variable costs and the average amount paid for each fixed cost. The calculation of these costs is given in Appendix A. Depreciation costs were not included in this study, because the age of the crabbing vessels ranged so greatly that it was impossible to assign mean value in useful life numbers.

Net revenue levels for the crab potting season were calculated for each firm in the survey. Because there really is no "average" firm, income levels are reported in Table 14 as averages for different firm classes, defined by region and size of operation.

Table 13: Fixed and Variable Costs

Cost:	
Variable Costs:	**Cost per unit:**
Pot costs	$ 20.45 a pot
Bait costs	$ 10.00 a bushel
Fuel costs	$ 0.99 a gallon
Labor Costs	$ 4.35 an hour
Misc. Costs	$ 2 a pot
Fixed Costs:	Average cost
Boat Maintenance	$ 506
Engine Maintenance	$ 485
Docking Fees	$ 158
Boat Insurance	$ 100
License Fee	$ 48

Table 14: Revenues and Costs by Firm Class

Sector:	Total Revenue	Total Costs	Net Revenue
Small Operator	$ 6,965	$ 2,776	$ 4,199
Medium Operator	$ 21,729	$ 8,906	$ 12,823
Large Operator	$ 45,428	$ 22,836	$ 22,591
Region 1 potter	$ 27,501	$ 13,186	$ 14,316
Region 2 potter	$ 23,192	$ 10,126	$ 13,066
Region 3 potter	$ 22,678	$ 10,369	$ 12,310
Hard and Peeler	$ 26,058	$ 10,516	$ 15,542
Hard Only	$ 25,287	$ 12,086	$ 13,201
Peeler Only	$ 13,255	$ 4,517	$ 8,738

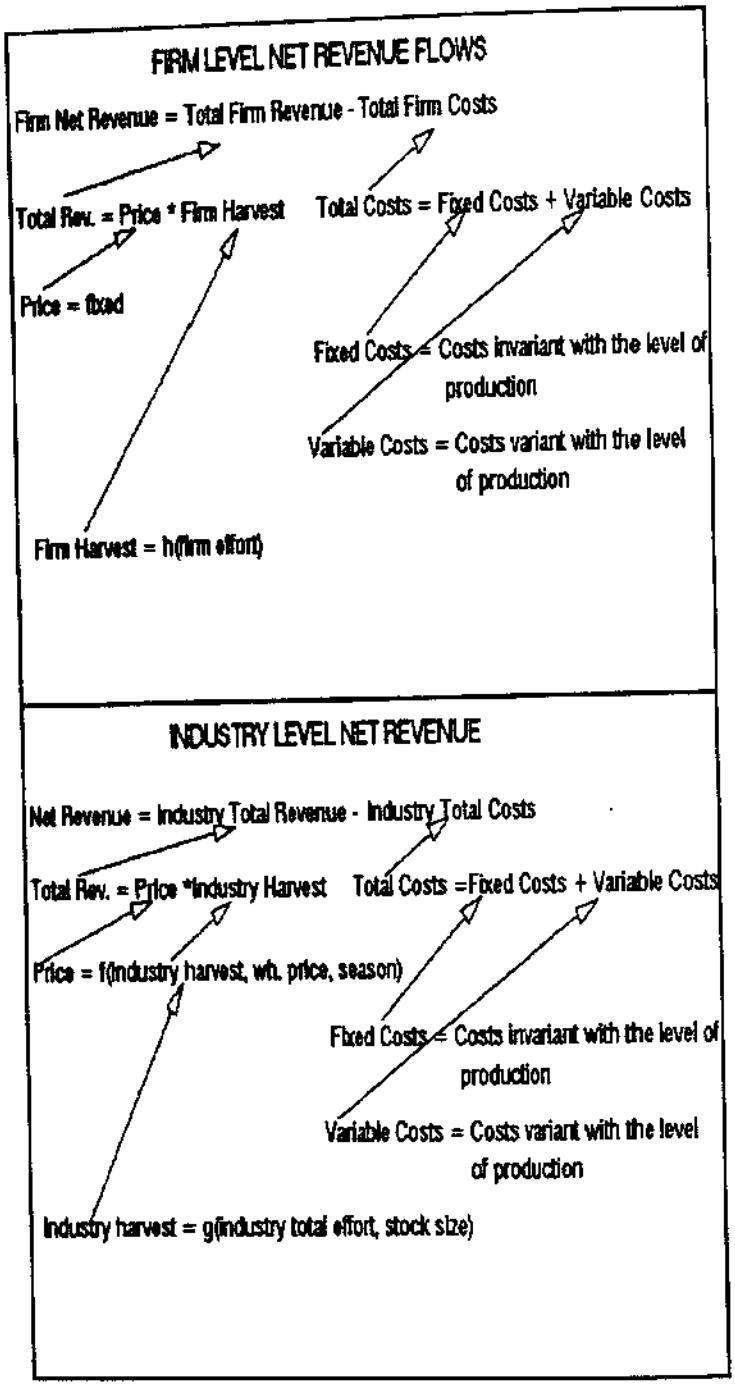

Figure 9: Net Revenue Flows for the Individual Firm and the Industry

VIII. The Income and Harvest Effects of Alternative Policy Actions

Because the blue crab fishery has been under much public scrutiny over the last few years and especially since the "low" harvests of 1992, many different policy actions have been discussed. Among these are limiting the number of gear licenses issued, limiting the number of pots an individual can fish, and limiting the amount of daily catch per person. This study simulated the harvest and income effects of these and other policies in an attempt to find out what their real impact would be.

More specifically, the harvest-price-income relationships were modelled to see if harvest decreases increased price levels enough to keep income levels at the same or a higher level. Also the relationship between a drop in harvest and variable cost levels was examined to test whether or not cost decreases could compensate for lower quantities.

The findings of these simulations are given below. It is important to note that while many of these policies had only small impacts on income and harvest levels for the fishery as a whole, there were some rather large distributional effects among firm classes, especially among different firm sizes.

Base Case Scenario

Table 15 presents the results for the base case, the 1992 blue crab fishery in Virginia with no new policies in effect. Total industry harvest levels, revenue levels, and cost levels are shown along with the numbers for the average crab potting firm. Some important factors to consider when viewing these numbers are: 1) These numbers do not include depreciation costs on the crabber's boat, engine and truck or transportation costs to a marketing channel, and 2) the harvest numbers do include Maryland crabbers who pot in Virginia, but the assumption was made that these people will sell their catch in Maryland and have no effect on price, and hence net revenue, in Virginia. The average annual net revenue for a Virginia crab potter is $13,658. This number includes a large number of part-time crabbers who may have other sources of income.

Policy Alternatives

Management policies can either attempt to change fishing behavior from the input or the output side. Limited and delayed entry schemes, and restrictions on pot use are all policies which regulate the use of inputs, be it labor or gear. Quotas, transferable or not, limit the output of a firm. Table 16 summarizes the expected *first-round* effects of some representative management policies. These are the effects which will be simulated over the 1992 season. Both input and output restrictions will reduce total harvest levels, increasing prices.

Input restrictions will raise the average product of effort, by reducing the level of effort (either labor or gear inputs). Limited entry scenarios reduce the number of people in the fishery, with price and harvest effects that raise incomes for those left in the fishery.

Pot limits reduce harvest levels for some firms, increasing prices, thus increasing revenues for the smaller firms. Limited entry can be combined with pot limits in order to reduce both gear and labor inputs. Another means of limiting inputs is to shorten the length of the potting season.

Output restrictions tend to reduce input costs for firms, as they are forced to contract the scale of their operations. Only individual quotas with an overall harvest quota policies will be simulated in this study. Quotas allow firms to choose how they will reduce their inputs, either through fishing less pots or by shortening the length of their potting season (either fishing fewer months of the year or less days per week).

A third way to raise industry incomes is by price increases caused by factors outside of the harvesting sector, such as wholesale price increases or declines in the processing margin. These policies raise everyone's incomes, without decreasing harvest levels or forcing people out of the fishery.

The results of the simulations for the overall average firm and for average firms within classes are given in Appendix C. For exposition's sake, the base case statistics will be indexed to 100, with all other policies shown as a difference from this index of 100. The next sections present the procedures used to run policy simulations and some general results.

Limited Entry. For the purposes of this simulation a reduction in the number of crab pot licenses issued was considered an entry limitation. It was assumed that a limited entry scheme would be implemented by not allowing any new people in the fishery, so that all those who had not renewed their licenses would be dropped. 22.6 percent of the license-holding population left the fishery after 1989. 15.1 percent of these transients were noncommercial watermen, while the remaining 7.5 percent were commercial crabbers. These percentages were used to delete the corresponding percentages from each firm class, by a random process.

The results of this simulation show that a 22.6 percent drop in the number of people who held crab pot licenses causes an 11.3 percent drop in total industry harvest levels. Harvest does not drop as drastically as number of people because almost three-fourths of those removed were noncommercial crabbers who have no effect on marketable harvest levels. Net income for the industry declines, but increases for the average firm, because there are less people in the fishery.

Pot Limits. One concern of many crabbers is the presence of large potters in the Bay who fish as many as 600 pots a day. There have been complaints that these large operators are glutting the market with crabs and keeping exvessel prices down. Another concern is that these large potters are making it difficult for smaller operators to make a living, by taking such a large share of the harvest.

Three simulations were run with pot limits set at different levels - 250 pots, 300 pots, and 350 pots. These simulations were implemented by reducing any firms who fished over the limit down to the maximum allowable number of pots. These policies, therefore, had impacts on the cost and harvest levels of some individual firms, and because total harvest levels in the fishery decreased, prices increased.

None of the pot limits managed to raise net revenues for the average firm, but the 300 pot limit reduced industry harvest levels by 6.3 percent and kept net revenue at the same level. However, as reported below, the median net revenue values increased from the base case, indicating a more even distribution of net incomes.

Median net income base case - 10,652
Median net income 250 pot limit - 10,972
Median net income 300 pot limit - 10,849
Median net income 350 pot limit - 10,732

Those who benefit most from pot limits are crabbers in region 2, small operators and those who peeler pot only. These are the people who probably did not have to reduce their pot numbers by much, and hence the only effects of this policy on their incomes was an increase in prices paid. Under the 250 pot limit, the large operator class (those who fish 300 pots or more a day) was eliminated and all large crabbers became medium size operators. The validity of making this assumption is discussed in the following section on distributional adjustments.

Another important result to emerge from the pot limits simulations was that Maryland crabbers, because they tend to fish a large number of pots (up to 600 a day) lost a

significant portion of their harvest. The numbers for Maryland harvest levels are reported below:

	Average Harvest	Percent Change
Base case	71,523.97	0
250 pot limit	50,435.95	-29.5%
300 pot limit	58,254.20	-18.5%
350 pot limit	62,365.21	-12.8%

Peeler Pot Limit. This policy limited peeler potters to 100 pots or less fished per day. This policy addresses concerns within the industry that peeler potting is damaging to the blue crab population because it removes females who are preparing to spawn. The results of this simulation show industry harvest levels declining less than 1 percent and income declining less than 2 percent. The only license holders who are seriously affected by this policy are those who only peeler pot, and their harvest levels are reduced 20 percent, with a 9 percent drop in income levels. The average income of large crabbers goes up by almost 7 percent only because the large crabber class has been reduced in number and is now made up entirely of hard crabbers, who tend to have higher income and harvest levels than peeler potters.

Limited Entry Combined with a Pot Limit. A policy which addresses both concerns of low income levels and inequity of distribution could be combining a limited entry scheme with a set pot limit. This policy was simulated by first reducing all crab pot licenses according to the limited entry scenario outlined earlier and then limiting the remaining people in the fishery to 300 pots.

The results of this simulation were that average net revenue for the individual firm increased, but industry net revenue levels declined along with a significant decrease in harvest levels. Income increased most for small operators, while large operators had a 10 percent decline in harvest levels but no decline in income. Those in region 2 and those who only peeler pot also get a 3 to 4 percent increase in net revenue. The median income level was also higher than the base case at $ 11,155, which was also higher than under the pot limit scenarios.

Limited Potting Season. This scenario was implemented by assuming that potting was banned in the months of March and November. This ban affected only hard crab harvests, because, in this study, no soft crabs were harvested in these months. One important difference of this policy is that there are no price effects to compensate for decreases in harvest levels, since the monthly hard crab exvessel price is only a function of landings in that same month.

This policy decreased net revenue for all firm classes, except for those who peeler pot only, as their harvest, cost, and revenue levels remain the same. This policy did manage to achieve a reduction of 7 percent in harvest levels, however. Incomes declined more for crabbers in region 1, large operators, and those who hard crab pot only.

Quota. Quotas, in contrast to the other policies considered so far, place direct restrictions on the output (rather than the inputs) of a firm. If an imposed quota is lower than a firm's current output level, the firm has alternative ways to reduce its inputs. The waterman may choose to fish less pots or shorten the length of his potting season (either fishing fewer months of the year or less days per week).

A individual daily quota was simulated, as this is the most likely way a quota would be implemented in the fishery. A 10 bushel a day quota for hard crabs was set, which translates into a 9600 pound quota for a month. This policy was simulated by reducing the number of pot days fished in a given

month for all firms which caught over 9600 pounds of hard crabs.

A 10 bushel daily individual catch limit for hard crabs was placed on all firms. With this simulation, industry harvest levels decline by almost 20 percent, with individual net revenue declining only 10 percent on average. Net revenue for small operators goes up by 4 percent, while those in region 1 and large operators are affected the most, with a drop in income of around 20 percent. There were no effects on peeler potting only firms because the policy was simulated only for a hard crab quota. Those who hard crab pot only have an 18 percent decrease in harvest and an 11 percent decrease in net revenue.

Conclusions of the Simulations

The policy simulations looked at the effects of alternative policy actions on both harvest and income levels in the fishery. A decline in total industry harvest levels often causes a decline in income for the average crab potting firm. Figure 10 shows the tradeoffs between harvest and income that occurred under 6 different policy scenarios. The policies considered were the base case, the 10 percent reduction in all crab pot licenses, the 300 pot limit, limited entry combined with a pot limit, the closed season on potting, and the 10 percent quota reduction. Limited entry reduces harvest by 10.2 percent and raises average net revenues by 4.2 percent, while the pot limit reduces harvest by 6.3 percent and keeps income at the same level. Both the quota and the closed season on potting reduce both harvest levels and average net revenues in the fishery.

Another important consideration of the simulation results are the distributional effects among firm classes. Policies such as quotas and pot limits tend to decrease incomes for those with larger operations, who tend to be in Region 1. A pot limit also tends to reduce the variance of income levels within the industry, addressing concerns of equity as well as those of overharvesting. A closed season policy tends to hurt only hard crabbers, as the peeler crabbing season is shorter and more dictated by biological and environmental factors. Quotas also have a negative income effect on only hard crab potters, as peeler crab harvest levels are only less than one-fiftieth of total blue crab harvest levels.

Another important conclusion to be drawn from the simulations is that the fishery is a high variable cost industry. Reductions in pot days fished tend to cause larger decreases in cost levels than in harvest levels. This is because as pot days fished decreases, so do fuel, bait, and labor costs, which constitute a high portion of the waterman's total costs.

The effects of Maryland watermen who crab pot in Virginia waters are also significant. Maryland crabbers take approximately 5 percent of total Virginia blue crab harvest and average 360 hard crab pots fished per day. Since it was assumed that Maryland crabbers do not sell their catch in Virginia, a 300 pot limit manages to reduce Maryland harvest levels by 18 percent while not reducing the average net revenues of crab potters in Virginia.

Summary

- Limiting entry is the only policy which reduces harvest and increases incomes, but it also keeps people out of the fishery
- Pot limits and quotas tend to increase incomes for small operators and decrease incomes for large operators, who come mainly from Maryland and the Eastern Shore of Virginia
- None of the policies considered have large effects on overall harvest and income levels

Table 15: Base Case Statistics

	Total Industry and Average Potting Firm	
	Total Industry	**Average Virginia Firm**
Peeler Harvest	2,034,055 lbs.	4012 lbs.
Hard Crab Harvest	58,665,974 lbs.	38,034 lbs.
Total Harvest	60,700,029 lbs.	35,452 lbs.
Total Revenue	$ 37,360,112	$24,272
Total Costs	$ 16,337,053	$10,614
Net Revenue	$ 21,023,059	$13,658

Table 16: First Round Net Revenue Effects of Alternative Management Policies

POLICY	RAISE PRODUCTIVITY OF EFFORT	CHANGE IN INPUT COSTS	INCREASE IN PRICES PAID
Limited number of gear licenses	policy limits labor and for those left in the fishery, catch per unit of effort may rise	as long as there is no input substitution, costs will not change for individual firms	drop in labor will decrease total harvest, increasing prices
Limited number of gear units per person	policy limits gear inputs and so catch per unit of effort increases, assuming the limit on pots is set so that some operations are forced to use less effort	Variable costs for some firms will decrease as they are forced to scale down their operations	drop in number of pots used will decrease total harvest, increasing prices
Limit length of potting season	policy bans effort in certain months, and so catch per unit of effort increases	Variable costs for some firms will decrease as they are forced to scale down their operations	drop in effort will decrease total harvest, but because prices are monthly, they will not increase
Daily individual quota (without overall quota)	no direct effect, but secondary effects will depend on the amount of the limit	Variable costs for some firms will decrease as they are forced to scale down their operations	drop in harvest levels will increase prices (assuming quota levels are below current levels)
Individual non-transferable quota (with overall quota)	no direct effect, but secondary effects will depend on allocation of quotas and size of overall quota	Variable costs for some firms will decrease as they are forced to scale down their operations	drop in harvest levels will increase prices (assuming quota is below current levels)
Product promotion and/or technological change in the processing sector	no direct effects	no change	prices will increase, either due to lower processing costs or to higher wholesale and retail prices being paid

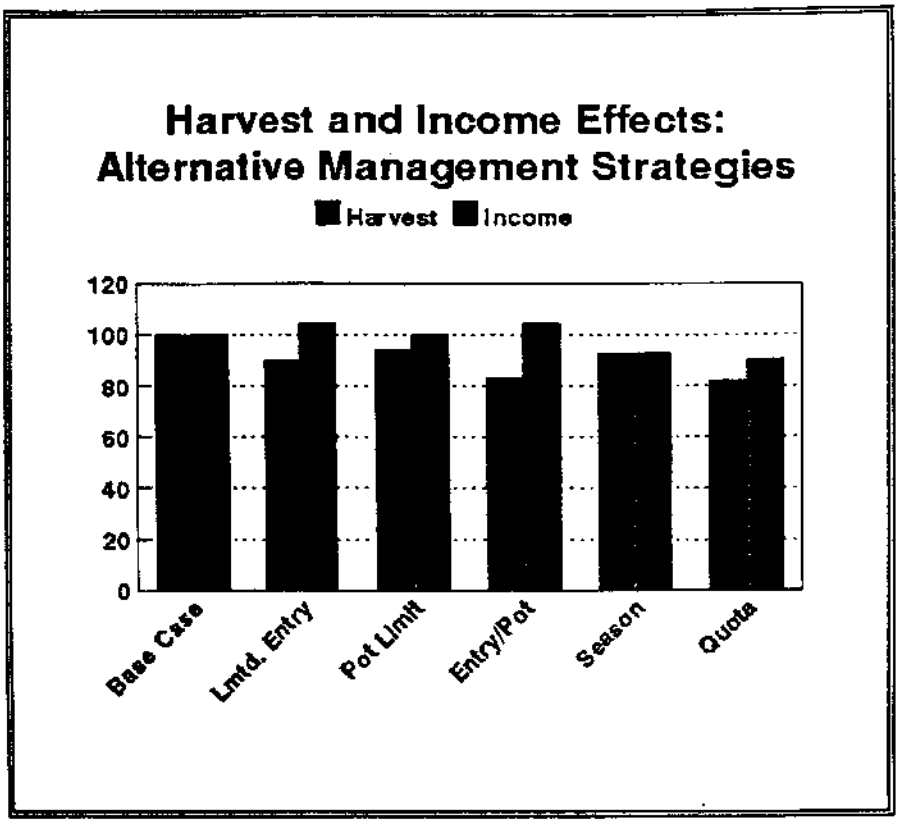

Figure 10: Harvest and Income Tradeoffs of Policy Simulations

IX. Real World Issues

The results of the policy simulations given in the previous section are based on the assumptions that

- there is 100 percent compliance with new regulations, and
- there are no dynamic adjustments after new regulations have been placed

Both of these assumptions are too simplistic for the real world. This section will examine these issues and what implications these issues have for future policy making.

Distributional and Dynamic Adjustments

One important conclusion to emerge from the pot limit scenarios is that some watermen move to a smaller firm class. When a 250 pot limit is enacted, there is no longer a large-firm category of potters, as these crabbers are forced to scale down the size of their operations. While the simulations of this study assume that all large crabbers become medium-sized firms, there is no guarantee of this.

Many larger operations may find, because of large fixed costs, that they cannot operate at reduced levels and they may drop out of the fishery. This is an important second-round effect which should be considered by policy-makers, even though it cannot be modeled in this study.

Another important factor to consider are the second-round adjustments made by smaller operations. (See Appendix B). Suppose a daily 300 pot limit were put in effect in the blue crab fishery. Many firms would be forced to cut back on the scale of their operations. This would cause harvest levels in the fishery to drop, increasing exvessel prices. Incomes for those who had always fished 300 pots or less would increase, due to higher prices. The opportunity cost of not crab potting would be higher because the return to effort of potting would increase due to higher prices. In effect, the higher exvessel price is an economic signal to increase effort in the fishery. Those who were fishing under 300 pots would increase the number of pots they fish and new people would join the fishery. After these adjustments, effort could be higher than it was before the pot limit. The same round of effects will take place under a daily quota system.

A similar dynamic effect will occur under a limited entry scheme. Even though there is a restriction on the number of people allowed in the fishery, there is no restriction on the number of pots a person can fish, and as people see prices increasing, they will increase their effort, i.e. fish more pots. A policy which limits both entry and the number of pots fished each day will be able to more effectively control effort and harvest, but as the next section pointes out, these policies have problems of monitoring, enforcement, and social acceptance.

Marketing Adjustments

Policies will have effects beyond the harvesting sector of the fishery. As harvest levels begin to drop, there will be adjustments in the processor, wholesale, and retail sectors. Anecdotal evidence suggests that when Virginia harvest levels are down, processors can and will obtain live crabs and/or picked meat from other states and even from Mexico. In 1992, one crab processing plant in Virginia attempted to get approval from the Virginia Department of Health to import blue crabmeat from India. The issue has not yet been resolved.

These effects are important because they indicate that there is the possibility of

substitution for Virginia blue crabmeat, which implies that the increased price effect of decreased harvest levels may not hold, as the market adjusts over a period of time.

Monitoring and Enforcement Costs

One of the main problems of real-world policies are the costs of monitoring and enforcement. The crab pot fishery in Virginia encompasses over 2500 people, who crab in many different rivers and creeks in addition to the Chesapeake Bay. There are private and public docks and close to half a million pots in the water. Talks with crabbers and VMRC personnel indicate that the enforcement of current regulations in the fishery is problematic, with only sporadic checks and inadequate personnel. In the survey, over 80 percent of the respondents agreed that better enforcement of size and catch limits was needed in the fishery.

One problem with limiting the number of pots is enforceability. It is rather difficult (nearly impossible) to monitor how many pots each waterman is fishing. Unless each gear unit is licensed in some way that can be enforced and monitored, the policy will be ineffective. How many bushels each waterman catches may be difficult to determine if he sells his crabs through more than one marketing channel or retails them directly. Monitoring must be done at the dock rather than at the processing plants to ensure compliance.

The literature on enforcement costs has shown that the number of violations against a particular law is a function of the following factors:

- Probability of being caught * penalty for being caught
- Profits from illegal activity
- Social acceptance of the policy and its goals

A study done by Furlong of fishery law violations in Canada found that the highest violation rate out of six different fisheries was in the offshore crab fishery. The policies considered in this study for crabs were gear unit limits and size of catch limits. Furlong concludes that violations are high in the crab fishery because, "monitoring is more costly and therefore less pronounced." (Furlong, 1991)

These issues demonstrate that when deciding what types of policies to implement, fishery managers must consider how enforceable the policy is and how much support there is for such a policy among watermen. The most easily enforceable policies considered in this study are limited entry and a limited potting season.

These policies, however, may have problems of political palpability. One of the problems with a limited entry scheme is where to set the limit on the number of people allowed in the fishery. If the limit is set only so that new people cannot obtain a gear license, then there is no reduction in labor supply. If the limit is set below the current level of labor in the fishery, there is the question of who gets a license. Limited entry schemes have historically been socially unacceptable with regard to the basis for limiting entry (Rickhus, 1992). However, 41 percent of the survey respondents agreed strongly that limits on the number of hard crab pot licenses issued were needed.

A 1988 publication by the Mid-Atlantic Fishery Management Council concludes, "If a regulation cannot be adequately enforced (and particularly if it is considered unfair), it will be widely ignored and ultimately cause contempt for the system which created it" (MFMC, 1988).

Watermen's Attitudes Toward Alternative Policy Actions

One important consideration in deciding what type of policies to implement is the degree of compliance among those who are affected. It is necessary, therefore, to examine the attitudes of the crabbers towards alternative policy actions. The 1992 survey gathered much information on this subject, not only through specific attitude questions, but also by allowing crabbers to express their own opinions in the final comments section of the survey. Over 70 percent of the surveys returned had comments from the watermen on them and most of these comments related to policy-making. An analysis of these comments again suggests that policies must consider the diverse nature of the fishery. In general, large operators tend to favor policies such as limited entry and the removal of part-time crabbers (those who derive less than 50 percent of their income from potting). Small operators favor pot limits and quotas, policies which generally effect only larger operations. The only policies which all crabbers seemed to agree on were limits on the winter dredge fishery, which would help all potters since it could increase the price they receive in the end months of the potting season.

Many non-commercial potters favored a limited season on crabbing, but not many commercial potters liked this idea, since they tend to receive higher prices in March and April when the crabs are scarce. Many potters also complained about the Maryland crabbers who pot in Virginia waters, pointing out that the Marylanders are large operators who are "stealing" their harvest. The overall tone of all the comments, however, was a consensus that new policies are needed in the fishery to control harvest and raise prices. Over 85 percent of crabbers agreed that the prices they received were too low. Many crabbers also expressed distrust of the VMRC, stating that policy decisions were often made without regard to their effects on the waterman. These kinds of attitudes do not bode well for future consent-building in the fishery.

Summary

- The most easily enforceable management policies are limited entry and a limited potting season
- Pot limits and quotas would be nearly impossible to effectively enforce, especially if they were not supported by the watermen
- In the long run, restricting only one factor of effort will not decrease harvest levels in the fishery

X. What Conclusions Emerge from this Study?

An important conclusion to be drawn from this work is that watermen do not make much money from crab potting. The average income of a medium-sized commercial crab potter for 1992 was $ 12,823, which does not include paying for a boat or engine or for transportation. In contrast, the average annual income of construction laborers (another job with significant requirements for physical stamina) in Virginia was $22,522. These results and this comparison indicate that income opportunities in this fishery are quite limited. If crab population and harvest begin to fall, exit of effort from the fishery may follow from these market forces. It is also important to recognize that this fishery is not the major source of income for the majority of its license holders. Policy impacts on income will only affect a portion of the waterman's total income.

Another important finding of this study is the characterization of the blue crab fishery. This fishery was found not to be capital intensive as some fishery managers and watermen claim. Instead the majority of watermen are small-scale, working from small boats and fishing fewer than 200 pots and can easily enter and exit. A small segment, about 15 percent of license-holders are large-scale, fishing up to 600 pots a day with large boats. Because of these characteristics, policy actions tend to have large distributional effects. Pot limits and quotas tend to decrease incomes for large operators, but increase them for the smaller crabbers. Limiting entry tends to remove the smaller crabbers from the fishery, while raising incomes for the larger operations.

The diversity of the fishery is also captured in the finding of a large non-commercial sector, almost one-third of crab pot license holders. There is also a large recreational sector, which is not counted among license-holders or in published harvest estimates. Including all sectors of the blue crab fishery is important for gathering accurate data for policy analysis.

Much has been written about and debated over in the blue crab fishery, but little in-depth analysis has been done. This study has shown conclusively that there are serious underreporting problems in the published data on the blue crab fishery, both in harvest and price levels. This appears to mainly be due to the voluntary reporting system that was in place until 1993.

In 1993, a mandatory reporting plan was put in place for all of Virginia's fisheries, whereby each waterman must fill out a daily record of his catch and the price he receives. This policy has generated much rancor among watermen who feel it is an unnecessary burden on them. The watermen feel they are not benefitting at all from this policy. According to the literature on fishery law violations, this will lead to watermen evading the policy and providing incorrect information.

This study has provided an alternative and effective method for gathering data in the fishery, through a series of monthly surveys. The survey instrument was well-accepted by the watermen, with over a 60 percent response rate and over 75 percent of the responses providing comments on fisheries policy. If this type of system were continued over a period of years, each waterman would be surveyed once every two years and only asked to provide a month's worth of data for his operation. In the end, this type of sampling, rather than a full census, would probably gather better data, not only because the information it would provide would be more complete (marketing channels, characteristics of the firm), but also because it would engender support among the watermen who are the ones who must comply with new fishery regulations.

Perhaps the most significant finding of this study is that the current information on the Virginia blue crab fishery too often is incomplete. Also, it appears that fishery managers should consider all the effects of alternative policy actions, including the high costs of monitoring and enforcement and the degree of self-compliance needed among the watermen, in evaluating policy alternatives. In order to effectively monitor the fishery, managers need both a better picture of the effort and harvest into and out of the fishery and a better understanding of policy impacts and watermen's attitudes.

Conclusions

- In order to build a comprehensive database on the blue crab fishery in Virginia, the sampling, aggregation, and other statistical procedures used in this study should be implemented on a continuing basis
- Policy impacts are dictated not only by the diverse nature of the fishery but also by costs of enforcement, social acceptance, and dynamic adjustments and these forces should be carefully analyzed before policies are implemented

REFERENCES

Anderson, Lee G. 1986. The Economics of Fishery Management. Baltimore: John Hopkins University Press.

Blue Crab Subcommittee of VMRC. Minutes of Meetings, 1990-1992.

Casey, James. 1992. Personal Communication, February.

Chartier, Nancy. 1988. "Larval Blue Crabs...finding the right habitat by chance or by choice?", Virginia Marine Resources Bulletin. Gloucester Point, VA: Virginia Institute of Marine Science, (Winter), pp. 6-7, 19.

Chesapeake Bay Commission. 1991. Annual Report to the General Assemblies of Maryland, Pennsylvania, and Virginia. Annapolis, MD: Chesapeake Bay Program.

Chesapeake Executive Council. 1989. Chesapeake Bay Blue Crab Management Plan. Annapolis, MD: Chesapeake Bay Program, July.

Chowning, Larry S. 1990. Harvesting the Chesapeake. Centreville, MD: Tidewater Publishers.

Cunningham, Stephen, Michael R. Dunn, and David Whitemarsh. 1985. Fisheries Economics: An Introduction. New York: St. Martin's Press.

Dressel, David M. and Donald R. Whitaker. 1982. An Economic Profile of the Blue Crab Industry. Washington, D.C.: National Marine Fisheries Service.

Furlong, William J. 1991 "The Deterrent Effect of Regulatory Enforcement in the Fishery." Land Economics. 67(February): 116-129.

Giuranna, Anne. 1993. "Income and Harvest Effects of Alternative Management Policies on Commercial Crab Potters in Virginia." Thesis: Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University.

Hong, Gi-Pyo. 1990. "A Technology Analysis of the U.S. Atlantic Blue Crab (Callinectes sapidus) Processing Industry." Dissertation: Department of Food Science and Technology, Virginia Polytechnic Institute and State University.

Hudson, Michael and Oral Capps Jr. 1984. "Forecasting Ex-Vessel Prices for Hard Blue Crabs in the Chesapeake Bay Region: Individual and Composite Methods." Journal of the Northeastern Agricultural Economics Council. (April): 112-118.

Mid-Atlantic Fishery Management Council (MFMC). 1988. Primer on Federal Marine Fisheries Management in the Northeastern United States. Dover, DE: MFMC, October.

National Marine Fisheries Service. 1973. Basic Economic Indicators: Blue Crab, 1947-1972. Washington, D.C.: US Department of Commerce.

Ner, Sonya. 1993. Personal Communication, June.

Nixon, Peter. 1992. Personal Communication, July.

Pearce, David W. and R. Kerry Turner. 1990. Economics of Natural Resources and the

Environment. Baltimore: John Hopkins University Press.

Rickhus, William, Herbert Austin, and Steven Nelson. 1992. "Fisheries Assessment and Management Synthesis: Lessons for the Chesapeake Bay." Perspectives on Chesapeake Bay, 1992 : Advances in Estuarine Sciences. Scientific and Technical Advisory Committee, Chesapeake Bay Program.

Shabman, Leonard and Oral Capps, Jr. 1985. "Benefit Taxation for Environmental Improvement: A Case Example from Virginia's Soft Crab Fishery." Land Economics. 61(November): 398-409.

Smoller, Ellen. 1992-1993. Personal Communication.

Tietenberg, Thomas H. 1992. Environmental and Natural Resource Economics. New York: Harper Collins Publishers.

US Department of Commerce and US Department of the Interior. 1991. Addendum to 1985 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Recreational Shellfishing in the United States.

US Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. 1970-1992. Fisheries of the United States. Washington, D.C.: Bureau of Commercial Fisheries.

Vance, Tamara Ann. 1982. "Returns to Effort Management in the Virginia Blue Crab Pot Fishery". Thesis: Department of Agricultural Economics, Virginia Polytechnic Institute and State University.

Van Engel, W.A. 1962. The Blue Crab and its Fishery in Chesapeake Bay. Washington D.C.: Commercial Fisheries Review.

Van Engel, W.A. 1973. The Edible Blue Crab...Abundant Crustacean. Washington D.C.: Atlantic States Marine Fisheries Commission.

Van Engel, W.A. 1985. "Predicting Blue Crab Populations", Marine Resources Bulletin. Gloucester Point, VA: Virginia Institute of Marine Science, Winter.

Virginia Department of Health, Shellfish Sanitation Division. 1992. Personal Communication, September.

Virginia Marine Resources Commission. 1992. "Commercial Crabbing in Virginia", Circular. Newport News, VA: VMRC.

Wesson, James. 1992. Personal Communication, February.

Whittaker, Louis. 1993. Personal Communication, March.

Appendix A: Explanation of Simulation Models

In order to predict the net income effects of alternative policy actions, a series of interactive models were built. These included price prediction models, physical equations of the production processes, and cost equations. The integrated simulation model may be viewed as a large spreadsheet with many cells, each of which contribute in some way to the overall calculation of net revenue levels for the individual firm. Figure A1 is a schematic representation of the model, showing all the individual calculations that go into a firm's net revenue.

Annual net revenue for the firm is equal to total annual revenue less total annual costs. Total annual revenue for the crab potting enterprise is equal to the sum of monthly revenues, which are the product of monthly exvessel prices and monthly firm harvest. The individual firm is a price taker, with exvessel prices determined by industry harvest levels and other exogenous factors. Harvest levels are determined by a combination of inputs, chief of which are the number of pot days fished by the firm. Total annual costs are the sum of monthly variable costs and annual fixed costs. Variable cost levels are also dependent on the number of pot days fished per month, as fuel, bait, and labor costs increase as pot days fished increases. Fixed costs are not dependent on input levels, but must be paid annually by the firm.

Total Revenue

Hard Crab Prices. Historically studies of blue crab prices have used a standard demand function, modelling quantity consumed as a function of prices and income. Two of these studies include one done by the National Marine Fisheries Service (NMFS) in 1973 for all crabs and one done by Dressel and Whitaker in 1982 for blue crabs. The NMFS study has an exvessel price elasticity of demand for all types of crabs equal to -.3, which implies that there is a significant inverse relationship between quantity consumed of all crabs (which is generally equal to quantity harvested) and exvessel prices. The Dressel and Whitaker study had a retail price elasticity for blue crabs equal to -.6. This finding demonstrates that there is a significant inverse relationship between retail blue crab prices and blue crab consumption. While these studies are important as indicators of possible relationships between prices and quantity, neither one gives any measure of the specific correlation between blue crab exvessel prices and quantity harvested. These studies also suggest that retail price may have a larger effect on consumption than exvessel price.

One missing element of the above studies is the analysis of seasonal variations. Those studies were based on annual rather than monthly data. There are seasonal fluctuations in both landings and prices in the blue crab industry. This is most important for hard crabs which have a limited shelf life. Stock supply, therefore, is dependent on landings. Prices for hard crabs tend to be lower in the late summer and early fall, when the harvest of crabs is at its highest. Figure A2 shows the seasonal variation in prices and landings for hard blue crabs in 1990. Soft crab prices are less variable as they are usually frozen and have a longer shelf life.

One study which did address the question of seasonality was done by Hudson and Capps in 1984. They estimated a monthly exvessel price formation equation for Chesapeake Bay hard crabs for the period January 1973 to July 1979. Their equation forecasted monthly exvessel price as a function of monthly landings, monthly retail and wholesale prices, and season of the year. Their results indicate that harvest levels do not have a significant impact on exvessel price. Their results also confirm that prices tend to be higher in the winter and spring and lower in the fall. Wholesale and retail prices were significant

estimators of exvessel prices, suggesting that the three sets of prices tend to follow each other.

The main purpose of the estimated price equation is to establish the nature of the relationship between harvest levels and exvessel price at the processing level, i.e., will decreases in harvest levels have a significant effect on price? Consequently the model be an inverse demand function, estimating hard crab exvessel price as a function of landings and other variables. Because of the seasonal nature of crab landings and of hard crab prices, the equation will be evaluated on a monthly basis.

An econometric model will be used despite the fact that Hudson and Capps concluded "generally speaking, it would appear that exvessel prices for hard crabs possess strong time dependencies, and consequently, better forecasts occur with time-series models than with econometric models." The time series models they recommend are not suited for testing the effects of alternative management policies and the harvest effect on price, which are the foci of this study.

The empirical model for hard crab price formation has the following form:

$$PHCex_{(t)} = B0 + B1(CBL_{(t)}) + B2(WPHC_{(t)}) + B3(JAN) + B4(FEB) + B5(MAR) + B6(APR) + B7(MAY) + B8(JUN) + B9(AUG) + B10(SEP) + B11(OCT) + B12(NOV) + B13(DEC)$$

Where

$PHCex_{(t)}$ = exvessel price of hard blue crabs in month t (dollars per pound of meat)

$CBL_{(t)}$ = Chesapeake landings of hard blue crabs in month t (Maryland and Virginia landings, 10 pound units)

$WPHC_{(t)}$ = Wholesale price of blue crab meat in month t (special grade, dollars per pound of meat, New York)

JAN =
FEB =
MAR =
APR =
MAY = monthly dummy variables
JUN = variable=1 for month=t, else variable=0
AUG =
SEP =
OCT =
NOV =
DEC =

The model was estimated over the period January 1981 to December 1991. Based on demand theory and previous studies, the price offered to the watermen is hypothesized to vary inversely with landings and the sign on B1 is hypothesized to be negative. The wholesale price, which represents demand by retailers, is hypothesized to have a positive effect on exvessel price, and the sign on B2 is hypothesized to be positive. Because exvessel prices are assumed to be reflections of the demand for hard crabs at the processor level, it is hypothesized that this demand is seasonal. Demand for crabs will be highest in the summer. Therefore, the signs on B3 to B7 and B10 to B13 are hypothesized to be negative, as the demand will be lower in the winter, spring, and fall as compared with the base summer month of July. The signs on B8 and B9, which represent the summer months of June and August will be indeterminate, as they will not vary much from July demand.

The model was estimated as a log-log function. The results of the regression are shown in Table A1. These results generally conform with theoretical expectations. The only months that were not significantly different from July were May, June, and August. All of the other parameters on the monthly indicators were negative, indicating that processor demand peaks in the summer months. There is also a significant inverse relationship between exvessel price and quantity of crabs harvested. The Durbin-Watson statistic is 1.3, indicating the presence of some serial autocorrelation, but it is not a significant problem.

The flexibility of exvessel price in this model is equal to -.245, indicating that a ten percent decrease in quantity will cause a 2.45 percent increase in exvessel price. The wholesale price elasticity of exvessel price is equal to .709, indicating that a ten percent increase in wholesale price will cause a 7.1 increase in exvessel price.

Table A2 reports the intercept variables for each month. These were obtained by adding the parameter estimates on the monthly variables to the intercept term. From these results, it appears that, all other factors equal, the prices offered for hard blue crabs is lowest in December, followed by March and February. Processor price offers are highest in the months of May through August, followed by April and September.

Production Processes

Production processes were modeled using monthly data from the surveys, with the number of pot days fished in the month hypothesized to be the main factor influencing harvest levels for a firm in that month. Other variables which were hypothesized to have influence included vessel length, years of crabbing experience, crabbing region, and season of the year.

Hard Crab Effort-Yield Function

A monthly log-log effort-yield function was estimated using data obtained in the 1992 monthly survey of crab potters for the months of March through November. A log-log function was used because there are diminishing returns to effort in the fishery. The number of bushels of hard crabs caught in a month was a function of hard crab pot days fished in the month, vessel length, crabbing region, years of crabbing experience, and season of the year. Initial runs of the model showed crabbing region and years of crabbing experience to be insignificant, and consequently these variables were not used in the final model. The results are summarized in Table A3. Fall was the only significant seasonal indicator, with catch levels higher in September, October, and November than in the rest of the months. In a sense, this variable captures some of the biology of the fishery, as blue crab stocks are thought to be highest in the fall months. Pot days fished was a significant estimator of monthly harvest, with a ten percent increase in pot days fished causing an 8.16 percent increase in harvest levels. Vessel length was also significant, with larger vessels catching more crabs. The adjusted R-squared was .74, indicating that harvest variation is well explained by the model variables.

Soft Crab Effort-Yield Function

A monthly effort-yield function for peeler crabs was estimated for the months of April through September[1]. Again, the model was a log-log function, with monthly peeler crab harvest a function of peeler pot days fished in the month, vessel length, years of crabbing experience, crabbing region, and season of the year. Vessel length and season of the year were not insignificant in initial runs of the model, and consequently were dropped from the final form of the model.

The results of the model are shown in Table A4. The signs on the parameters of the region dummy variables indicate that people in Region 2 and Region 3 tend to catch more than those on the Eastern Shore. This may be because of biological factors, with warmer waters in Region 3 and the bottom part of Region 2 and also the fact that soft crabs tend to migrate southward, with large runs in May and August. Crabbing experience was also significant, with those having more experience having higher harvest levels. A 10 percent increase in peeler pot days fished will cause a 4.3 percent increase in monthly peeler crab catch. The adjusted R-squared was .4534, indicating that about half of the variation in harvest is explained by the model variables.

Total Costs

Most variable costs were calculated on a monthly basis, dependent on whether or not a firm potted in that month. Fixed costs were calculated on an annual basis, as these costs are faced by the firm whether or not it crab pots at all.

Variable Costs

Pot Costs. To calculate annual pot costs for both hard crab pots and peeler pots, it was determined that pots are replaced approximately every 18 months and that 10 percent of pots must be replaced during the season, due to being lost, cut, or stolen. Therefore, for each pot bought, an additional one-tenth of a pot must also be paid for. The cost of getting a pot into the water (adding rope, buoys, and zinc anodes) was estimated at $18.50. The following equation was added to the spreadsheet model to calculate a firm's annual pot costs:

Potcosts = [(number of pots fished) * ($18.50 + $1.85)] /18 * months fished

Hard Crab Bait Costs. The survey responses indicated very little variation in the use of bait per pot over all months. Bait costs were estimated for frozen menhaden, which is the most commonly used form of hard crab bait used in Virginia. An average price of $10 a bushel was used, obtained in a telephone survey of selected watermen. Therefore, the average of cost of bait per pot was used to calculate each respondent's bait use for each month. The following equation was added to the spreadsheet model to calculate the firm's bait costs for each month in which it hard crab potted:

$\text{Bait cost}_t = .0185737 * (\text{Hard pot days fished})_t * \$10$

Peeler Crab Bait Costs. Peeler pots are usually baited only during the large peeler runs in May and August. They are baited with a large male crab to attract females who are preparing to moult. The average weight of a hard crab was estimated at .75 pounds and forty pounds in a bushel of crabs. The price the peeler crab pays for a bushel of hard crabs was estimated at $10, which was the average reported in a telephone survey of crabbers. In the spreadsheet, the following formula was used to predict bait costs for firms which peeler potted in May and August:

$\text{Baitcost}_t = [(\text{Peeler pot days fished})_t * .75] /40 * 10$

Fuel Costs. The first step in estimating fuel costs was to determine the time of each respondent's daily run to fish his pots. Because this information was reported only for those respondents who filled out Part II of the survey, a function was estimated so that hours for crabbing run could be simulated for each survey. The main estimator of hours of crabbing run was hypothesized to be number of pots fished, with other possible estimators being crew hired and month of the year.

Separate functions were estimated for hard crab and peeler crab runs. These functions are summarized in Table A5. The equations were estimated as linear functions. Hours for a hard crabbing run were a positive function of number of hard crab pots fished and an inverse function of number of crew hired.

The number of crew hired for each firm is explained in the next section. The adjusted R-squared for this function was .54. For peeler crab operations, run time was a function of number of peeler pots fished. The adjusted R-squared was .3052.

The average price of fuel for 1992 in Eastern Virginia was $.99, an average obtained in a telephone survey of crabbers. The following equations were added to the spreadsheet model to calculate a firm's monthly fuel costs:

Hard crab run hours = 2.820677 + .016336 * hard pots fished per day - .593276 * number of crew hired

where crew hired is explained in section 4.415

Peeler crab run hours = 2.908216 + .011077 * peeler pots fished per day

$$\text{Fuel costs}_i = \text{Run hours} * \text{gph} * (\text{pot days fished})_i * .99$$

where gph = gallons of fuel used per hour, answered by all survey respondents

Labor Costs. The amount of labor hired by each respondent was determined by the number of pots they fished. For hard crab operators, the following distribution was used:

< 250 pots fished per day	- no labor hired
250 to 349 pots	- 1/2 person
350 or more	- 1 person

For peeler crab operators the distribution was:

over 300 pots fished per day - 1 person

An average wage rate of $4.35 an hour was used as the cost of labor. The following formula was added to the spreadsheet model to calculate total labor hours used in a given month:

$$\text{Total hours}_i = \text{Amount of labor} * \text{run hours} * (\text{pot days fished})_i$$

Miscellaneous Costs. Additional variable costs faced by the crab potter, which were not asked for in the survey, include costs for ice for both bait and the crabs, costs of barrels and baskets to keep the harvested crabs in, and equipment costs such as gloves and boots. These costs were assumed to be higher for those who fish large numbers of pots per day. The following costs were added to the spreadsheet to cover miscellaneous expenses:

Miscellaneous costs = $2 x number of pots fished per day

Fixed Costs

All of the fixed costs calculated in the budgets, with the exception of license fees which were already known, were directly reported by all survey respondents. Each respondent provided their annual outlays on maintenance and repairs on their boat and engine, on boat insurance, and on docking fees. Each respondent also provided what percent of their income was derived from other fishing. The following formulas were added to the spreadsheet model to calculate each firm's annual fixed costs:

Docking fees = Total annual docking fees * (1 - INCFISH)

Boat insurance = Total annual boat insurance * (1 - INCFISH)

Engine Maintenance = Total annual engine main. * (1 - INCFISH)

Boat Maintenance = Total annual boat main. * (1 - INCFISH)

where INCFISH = percent of income derived from fishing activities other than crab potting

The cost of a crab pot license in 1992 was $48.00.

Net Revenue

Net revenue for each survey respondent was found by adding variable and fixed costs and subtracting this amount from their total revenue. Revenue, cost, and harvest variables for the Virginia blue crab pot industry were found by summing over all survey observations and aggregating from the sample to the industry, given the already known information that the sample was representative of the population. There were 299 commercial crab potters in the whole sample of 490, which represented 61 percent of the sample, and hence 61 percent of the license-

holding population of 2550. Therefore an aggregation factor of 5.2 was used. Non-commercial crabbers, which represented 32 percent of the population, were assumed to not sell any of their catch, and therefore, their harvest levels were not included in the harvest levels which fed into the price equations.

Table A1: Log-Log Model of Hard Crab Exvessel Prices

Dependent variable = log(exvessel price)$_t$		
Variable	**Parameter Estimate**	**P-Value**
Intercept	3.48547	.0001
Log (WPHC)	.709460	.0001
Log (CBL)	-.245482	.0001
JAN	-.666554	.0001
FEB	-.716764	.0001
MAR	-.832313	.0001
APR	-.283713	.0031
MAY	-.020727	.7919
JUN	.095942	.1597
AUG	-.082890	.2148
SEP	-.362773	.0001
OCT	-.574558	.0001
NOV	-.674288	.0001
DEC	-.895759	.0001
r-Squared = .8360 Adjusted r-Squared = .8142	D-W statistic = 1.3	

Table A2: Intercept Variables for Each Month

Month	Intercept
January	2.82
February	2.77
March	2.65
April	3.20
May	3.48
June	3.48
July	3.48
August	3.48
September	3.12
October	2.91
November	2.81
December	2.59

Table A3: Log-Log Monthly Hard Crab Production Function

Dependent variable: Log (bushels of hard crabs)$_t$		
Variable	**Parameter Estimate**	**P-value**
Intercept	-3.640389	.0001
Log (pot days fished)$_t$	.816460	.0001
Log (vessel length)	.505752	.0059
Fall*	.434556	.0279
*Fall = 1 for September, October, and November = 0 for all other months		
R-squared = .7608 Adjusted R-squared = .7554		

Table A4: Log-Log Peeler Crab Production Function

Dependent variable: Log (bushels peeler crabs),		
Variable	**Parameter Estimate**	**P-value**
Intercept	-1.09387	.3395
Log (pot days fished)	.432389	.0014
Log (experience)	.229239	.0969
Region 2	.883893	.001
Region 3	1.266357	.0023
R-squared = .5239 Adjusted R-squared = .4534		

Table A5: Crabbing Run Hours for Peeler and Hard Crabs

Hard crab run: Dependent variable = hours of hard crabbing run		
Variable	**Parameter Estimate**	**P-value**
Intercept	2.820677	.0001
Hard pots fished	.016336	.0001
Crew hired	-.593276	.0887
R-squared = .5498 Adjusted R-squared = .5416		
Peeler crab run: Dependent variable = hours of peeler crabbing run		
Variable	**Parameter Estimate**	**P-value**
Intercept	2.908216	.0001
Peeler pots fished	.011077	.0001
R-squared - .3391 Adjusted R-squared = .3052		

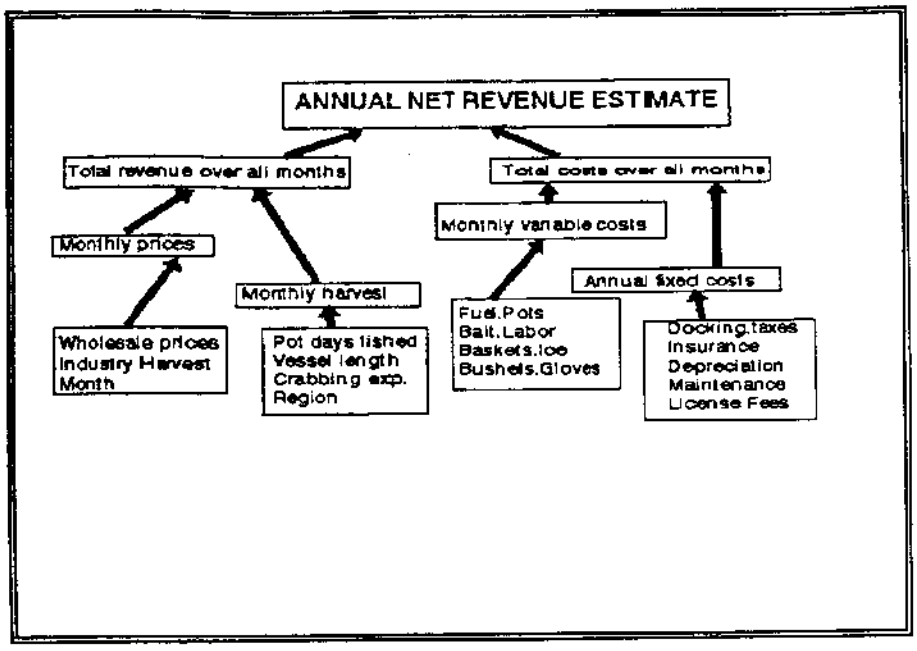

Figure A1: Revenue Flows for the Blue Crab Fishery

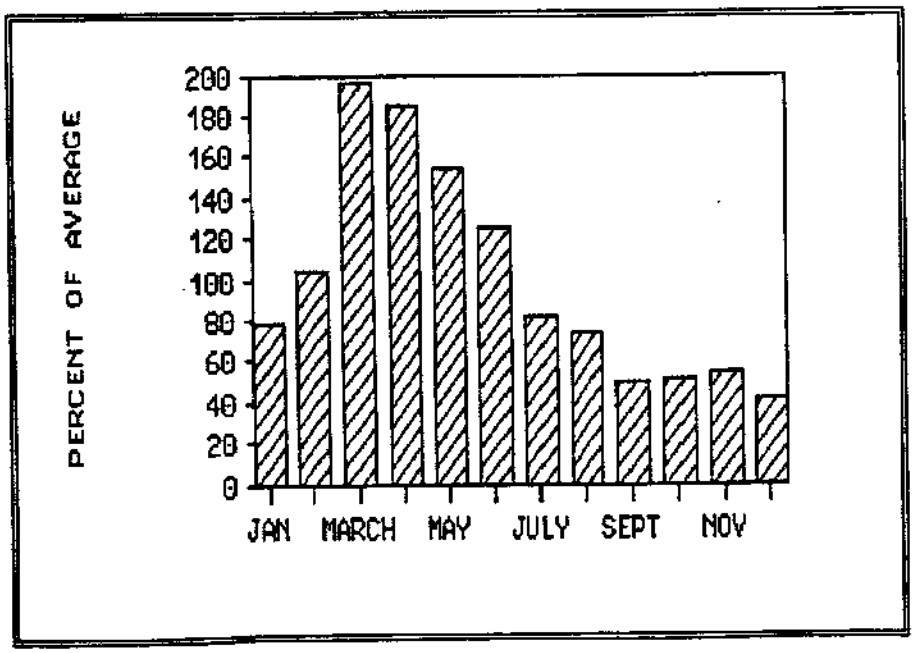

Figure A2: Seasonal Index of Hard Blue Crab Exvessel Prices, 1990

Source: National Marine Fisheries Service

Appendix B: Dynamic Effects of Alternative Policy Actions

This appendix looks at the second-round effects of input and output restrictions. Although these effects could not be modelled for this study since they will take place over a period of years, it is important to realize the long-term effects of management policies.

Input Restrictions

Limited entry reduces labor supply in the fishery. This raises the average product of effort for those left in the fishery. This result, however, assumes that those left in the fishery do not increase the scale of their operations, ie. fish more pots. There may, however, be no increase in net revenues if the people left in the fishery increase the number of pots they fish to the point where effort rises back to the initial level. People will be motivated to fish more pots if they see that their average product of effort is increasing (as there are more crabs to be caught in a fewer number of pots) or if they see the prices they are receiving increase.

These flows are shown in figure B1. Initially effort is at E1 in panel A. When limited entry is implemented, the ES curve shifts in to ES2, as effort supply is decreased. This causes effort to fall to E2, which in turn causes harvest to drop from H1 to H2 in panel B. This causes an increase in the price from P1 to P2 in panel C. This price increase will shift the average revenue curve outward and thus increase effort to a new level, say E3 in panel D. E3 may be less than, equal to, or more than the original level of effort E1. There is no guarantee, therefore, that this policy can cause a drop in total effort. There is also no evidence that watermen's incomes will increase in the long-run. Initially, watermen will have higher incomes due to the price increase, but if they increase their effort (and thus increase both costs and harvest level) their income may not stay at the higher level.

A second means of controlling inputs that was simulated was a limit on the number of pots a person can fish each day. Theoretically, this reduces the level of effort (if the limit is set so that some watermen must scale down their operations) and increases the average product of effort. There may also be some loss of labor in the fishery, because larger operators may no longer find it profitable to continue potting at the lower level of effort. This decrease of labor supply, however, was not simulated for this study.

There is, however, nothing to prevent new people from entering the fishery and fishing any number of pots up to the limit or for people who are currently fishing below the pot limit to increase the scale of their operations. This may occur because as the average product of effort increases, along with prices, the opportunity cost of fishing is lower and people will find it more attractive to crab pot than to do something else.

The main problems with policies that attempt to control the input side of the fishery is that they are generally limiting only one factor of effort for an individual fisherman and cannot control for substitution of effort factors within the industry. A policy which limits both entry and pot use is more effective in controlling effort. The next section outlines the dynamic effects of output restrictions and presents alternative methods for implementing quotas in the fishery.

Output Restrictions

Quotas are the main method use to control output within a fishery. They increase net revenue by reducing harvest and thus increasing prices paid to the watermen. Three types of quotas will be considered for the blue crab fishery - an individual daily quota with no overall fishery quota, an individual quota with an overall fishery quota, and a

transferable individual quota with an overall fishery quota. This study modeled only an individual quota without an overall fishery quota (10 bushel limit a day).

The first policy is one that has already been suggested for the blue crab fishery - that each waterman is limited to catching a certain number of bushels of crabs per day. While this may reduce the output of an individual firm, there is no guarantee that output for the industry will decrease, as people are free to enter the fishery, which they will be motivated to do if exvessel prices increase. This is not really a quota regulation because there is no cap on overall harvest levels in the fishery. This policy may distribute catch more evenly among watermen (like a pot limit), but it is not a revenue increasing policy for the fishery as a whole.

An individual quota which is based on an overall quota for the fishery does put a cap on total harvest levels for the industry and is the only one of the policies which has the ability to directly increase prices, assuming that harvest levels are set at lower than current levels. A quota system of this type would allocate either a certain number of bushels to each license holder or a certain percentage of the allowable harvest. Because there is a limit on total harvest, there is a limit on the number of people who can be allocated a portion of this catch. In this way, quotas are able to control for the problems of open access.

The idea of transferable versus non-transferable quotas is a question of firm-level efficiency. If firms are forced to catch a certain institutionally determined amount, it is possible they will be forced to operate at a point that is cost inefficient, ie., not at the minimum point on the average cost curve. Transferability of quotas allows firms to trade quota amounts so that they are at a more cost efficient level. A simple example will demonstrate this point. Suppose a TAH of 10,000 bushels is established for the industry and quotas are distributed in 100 units increments to 10 firms, so that each firm receives a 1000 bushel quota for the season. Figure B2 shows the cost structures for firms 1 and 2. Each firm faces a horizontal marginal revenue curve (MR) because effort at the firm level cannot effect price. Firm 1's marginal cost for harvesting 1000 bushels is above its marginal revenue, while firm 2's marginal cost for harvesting 1000 bushels is below its marginal revenue. Both firms are better off, if firm 1 purchases 1 quota unit (100 bushels) from firm 2, as long as firm 1 pays firm 2 less for the quota than firm 1 will make off of the extra harvest. The price of the quota will be determined by opportunity and transactions costs. After the trade both firms are operating "efficiently".

Another important consequence of this type of policy is that it motivates producers to find new technologies that lower the real cost of producing effort. As firms become more efficient, the industry as a whole becomes more efficient, and it is possible that industry effort will be closer to the sole owner rather than the open access equilibrium. Rents, to the people left in the fishery, will have increased, thus increasing individual net revenues.

The distribution of quotas is often a controversial subject. If they are to be transferable, then distribution is not so much of a problem, but if they are non-transferable, there are questions of both equity and efficiency to be addressed. Also, the establishment of an overall quota for the fishery is dependent on accurate data on population dynamics, the relationship between harvest and stock size, and the variability of the stock size.

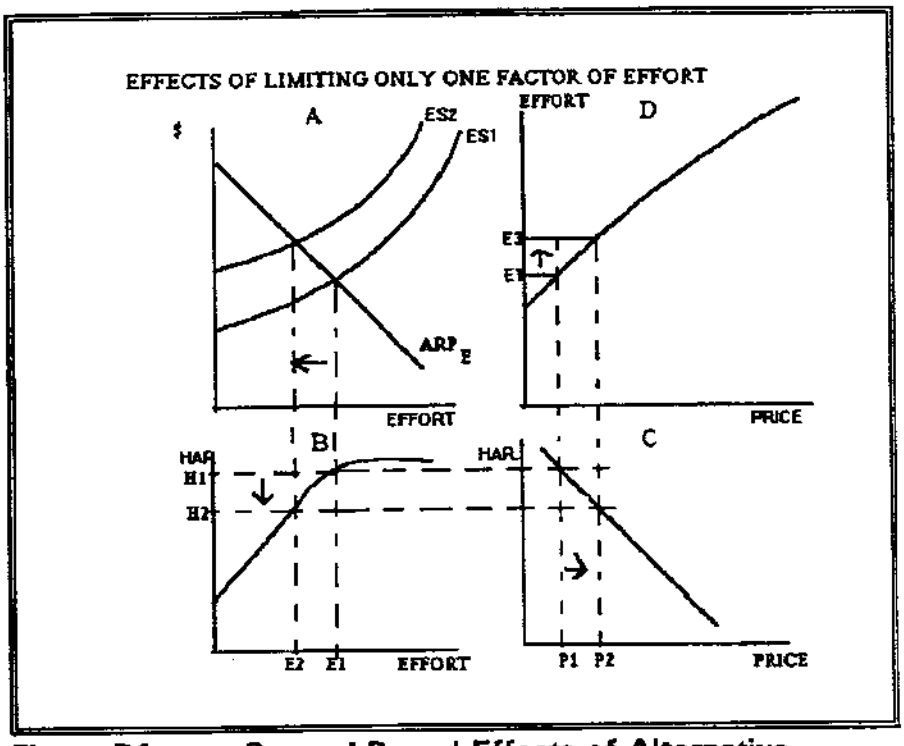

Figure B1: Second-Round Effects of Alternative Policies

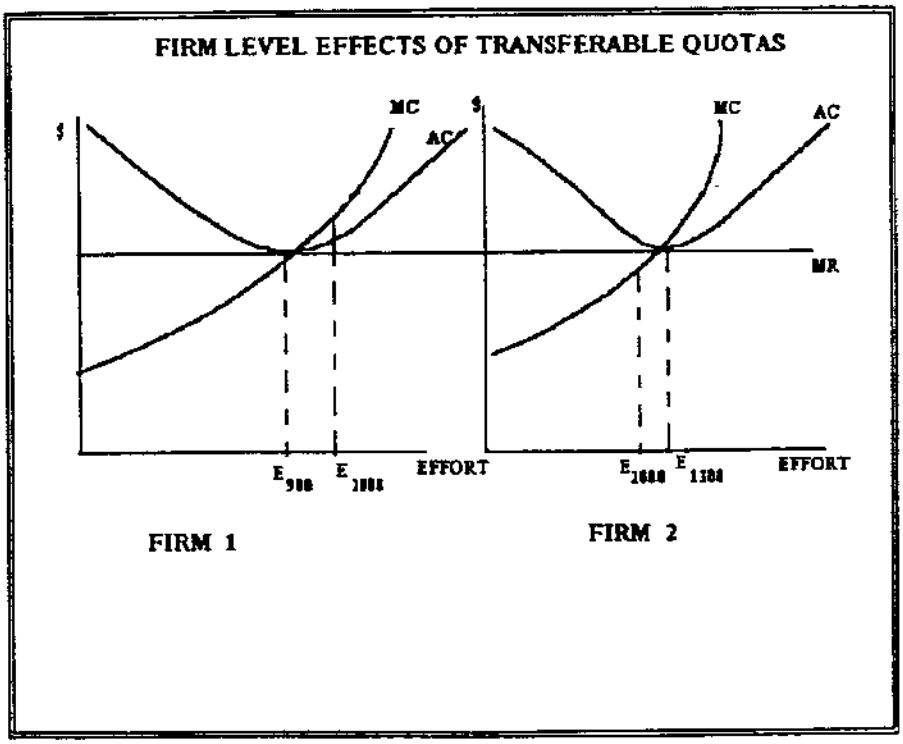

Figure B2: Individual Transferable Quota

Appendix C: Policy Simulation Results

The following pages present the policy simulation results for the following firm classes:

TH - Average hard and peeler crab harvest
TR - Average Total Revenue
TC - Average Total Costs
NR - Average Net Revenue

S = small operators, those who fish a total of less than 100 pots
M = medium operators, those who fish between 100 and 299 pots
L = large operators, those who fish 300 or more pots

HP = hard and peeler potting operations
H = hard crab pot only operations
P = peeler pot only operations

R1 = see region 1 classification in Text
R2 = see region 2 classification in Text
R3 = see region 3 classification in Text

Statistics are first presented for the industry as a whole and for the average firm.

1. Limited Entry removing transient watermen

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	88.7	100.3	103	100.2	101.3	92.9	100.5	102.9	101.4	101.1	96.5
TR	91.2	101.8	104.4	101.3	102.8	96.9	103.1	103.3	102.8	102.9	98.0
TC	89.4	99.8	102.2	100.3	100.4	92.2	100.6	104.4	100.6	102.0	93.8
NR	92.5	103.4	105.8	102.0	105.0	99.9	105.3	102.8	104.5	103.5	101.4

2. 250 pot limit

	Ind	Avg	S	M	L	HP	H	P	R1	R2	R3
TH	87.7	89.5	100	124.4	N/A	92.3	88.7	96.9	80.6	93.7	91.4
TR	92.7	92.7	101.9	122.7	N/A	95.8	91.3	94.9	85.0	96.6	94.6
TC	86.5	86.5	100	128.6	N/A	89.4	85.6	88.1	77.3	91.7	88.6
NR	97.5	97.5	103.2	118.9	N/A	99.7	96.3	101.0	91.5	100.2	99.3

3. 300 pot limit

	Ind	Avg	S	M	L	HP	H	P	R1	R2	R3
TH	93.7	95.0	100	100	89.9	96.4	94.6	98.4	88.7	98.2	95.5
TR	96.5	96.5	100.9	101.1	91.6	98.1	95.9	98.4	91.3	99.5	97.1
TC	92.8	92.8	100	100	86.5	94.2	92.5	91.7	85.8	97.0	93.7
NR	99.4	99.4	101.5	101.8	96.5	100.5	98.8	101.4	95.9	101.3	99.8

4. 350 pot limit

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	97.1	98.1	100	100	96.2	98.0	98.2	99.1	94.7	100	98.4
TR	98.7	98.7	100.3	100.4	96.9	98.8	98.6	99.1	95.7	100.4	98.9
TC	97.6	97.6	100	100	95.6	96.6	98.1	93.6	93.7	100	98.3
NR	99.5	99.5	100.5	100.6	98.1	100.1	99.1	101.6	97.5	100.7	99.4

5. 100 Peeler Pot Limit

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	99.3	99.3	100	96.2	113.9	97.8	100	79.7	98.2	99.8	99.9
TR	97.3	97.3	100	97.5	107.1	93.2	100	79.7	93.1	99.1	99.6
TC	95.9	95.9	100	96.0	107.5	88.5	100	57.8	88.8	99.4	99.7
NR	98.5	98.5	100	98.6	106.8	96.3	100	90.9	97.1	98.9	99.5

6. Limited entry and 300 pot limit

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	83.1	95.3	103.0	100.2	90.9	90.8	95.0	101.1	89.9	99.2	92.7
TR	88.0	98.3	105.3	102.5	93.9	95.9	98.8	101.5	93.5	102.2	95.6
TC	83.0	92.7	102.2	100.3	86.6	88.3	92.9	95.1	86.2	98.8	88.4
NR	91.9	102.6	107.3	103.9	100.8	100.7	103.8	104.4	99.7	104.8	101.3

7. No potting in March and November

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	92.9	92.9	96.6	93.7	91.9	91.6	93.2	100	91.5	94	92.5
TR	94.5	94.5	97.7	95.0	93.4	94.6	94.0	100	93.7	95.1	94.1
TC	96.1	96.1	98.1	96.5	95.5	95.7	95.9	100	95.7	96.5	95.5
NR	93.2	93.2	97.4	94.0	91.5	94.0	92.3	100	91.9	94.0	92.9

8. 10 bushel a day limit

	Ind.	Avg.	S	M	L	HP	H	P	R1	R2	R3
TH	81.8	83.3	100	94.6	74.8	87.5	82.1	100	75	87.3	84.9
TR	89.2	89.2	102.6	99.3	82.1	93.8	87.4	100	82	93	90.6
TC	88.5	88.5	100	96.8	81.4	93.2	86.3	100	84.8	91	88.5
NR	90.1	90.1	104.3	100.9	82.7	94.4	88.7	100	77.8	94.9	92.8

Appendix D: Sampling Procedures and Response Rates

This section outlines the procedures used to sample the crab pot license holders in 1992. The response results of the 1991 entry/exit survey were used to determine the sampling procedure for the 1992 survey. Only those who held crab pot licenses in 1990 were considered for sampling, a total of 2550 people.[2] 583 people who fit this criteria responded to the 1991 survey. These people, because they had responded to one survey were removed from the complete census and marked as the first list. These 583 people were tested for representativeness of the population of license holders using Chi-Square tests. The only population characteristics available for all crab potters are age and county of residence. The sample taken in the 1991 survey was found not to be significantly different from the overall population in either characteristic. Therefore there was no age or location bias in this sample. If any other bias existed, it could not be detected. Those who did not respond to the 1991 survey were removed from the list, as they would probably not respond to a second survey. After removing those from the list who were know to be deceased or had moved out of state, there were approximately 1250 people on the list who had not been previously surveyed. This 1250 comprised the second list.

A total of 1204 people were surveyed over the season. Because there were seven periods to be surveyed, 172 people were surveyed each period. These 172 people were drawn from two lists. The first list was the 583 people who had responded in 1991. Each period, 83 or 84 of these people were surveyed. These people were not drawn randomly, however. One of the questions on the 1991 survey asked the respondents in which months they usually crab potted. The list was divided over the months so that each person received a survey in a month in which they normally crab potted. This procedure assured a higher response rate for Part II of the survey than might otherwise occur. The remaining 87 or 88 people were drawn randomly from the previously unsurveyed license holders, using a random number generator.

The Dillman (1978) method was used in mailing the surveys. This method has three steps. First a questionnaire and cover letter were sent. A cover letter emphasizing the importance of the survey to fisheries policy was sent, and those on the first list (see below) were also sent the results of the fall 1991 survey.

Then in two weeks a reminder postcard was sent to those who had not responded. Two weeks later a second letter is sent as well as another copy of the survey form. In this survey, two different cover letters were sent with the first mailing. One letter was sent to those who had responded to the 1991 survey, thanking them for their response. The other letter, sent to those who had not received a survey in 1991, did not include the first paragraph of the other letter. For the October/November survey, no postcards were sent. All of the cover letters, the postcard, and the survey instrument are shown in Appendix A. The survey instrument is shown for the month of August.

The response rates for each period are shown in Table D1. 1204 surveys were mailed, 36 of which were undeliverable. The overall response rate for the survey was 62 percent. A total of 720 surveys were returned. Of this number, 490 were usable surveys, as a number of surveys were returned by those who did not crab pot in 1992 and some surveys contained incomplete information.[3]

The survey data was tested for representativeness of the crab pot license-holding population by performing Chi-square tests on the two statistics that were known for the population - age and county of residence.

The results of these tests are shown in Table 1. The Chi-Square statistics indicated no difference between the sample and the population, and therefore the sample will be considered representative of the population.

Table DI: Response rates for 1992 Survey of Crab Potters

Period	Number of Responses	Response Rate
	(Percent)	
March/April	97	58
May	95	57
June	103	62
July	113	68
August	110	66
September	115	69
October/November	87	52
Representativeness of Survey Responses		
	Chi-Square Statistic	
Age	.708	
County of residence	.545	

Appendix E: Survey Instruments and Cover Letters

Survey 1 : Entry/Exit

Survey Instrument:

The first 11 questions are for 1990 (or 1989).

1. In 1990, what else did you fish for?

   _____Oysters_____Finfish _____Clams_____Other

2. How would you describe your *off water* employment in 1990?

   _____ held another job in addition to commercial fishing

   _____ retired

   _____ student

   _____ unemployed

3. In 1990, how much of your annual income was earned from commercial fishing?

   _____ less than 50 percent

   _____ 50 - 75 percent

   _____ more than 75 percent

4. Which of the following describes your crabbing activity in 1990?

   _____ I was a crew member on someone else's boat.

   (if you were a crew member you need not answer any

   additional questions. Thank you for returning the survey)

   _____ I operated my own crab boat.

   _____ I operated my own boat and was a crew member on another boat.

5. Fill in the information about the vessel you used for crabbing in 1990.

   a. the length of the vessel was _____ feet

   b. the age of the vessel was _____ years

   c. the age of the engine was _____ years

   d. the engine was _____inboard _____outboard (check one)

6. Circle the months that you crab potted in 1990.

   Mar Apr May Jun Jul Aug Sep Oct Nov

7. When you fished peeler pots in 1990, about how many pots did you normally set out?

_____ pots

_____ I did not fish for peelers in 1990 (skip to question 9)

8. When you fished peeler pots, how many days per week did you normally fish?

_____ days per week

9. When you fished for hard crabs in 1990, about how many pots did you normally set out?

_____ pots

_____ I did not fish for hard crabs in 1990 (skip to question 12)

10. When you fished for hard crabs, how many days per week did you normally fish?

_____ days per week

11. In 1990, what percent of your hard crab catch did you sell to picking houses?

_____ percent

Now we want to ask questions about 1991 (this year).

12. Did you purchase a Virginia crab pot license for 1991?

____ yes (skip to question 14)

____ no

13. What was the *most important* reason you are not crabbing this year?

(Check only one and then skip to question 15)

_____ I have a full-time job off the water.
_____ I cannot make enough money in crabbing.
_____ I have boat/motor problems.
_____ The work is too difficult for me.
_____ Other (write in)

_____

14. What is the *most important* reason you decided to continue crabbing in 1991 (check only one.)

_____ It is a tradition. I have crabbed for many years.
_____ I made a good income last year.
_____ Other (write in)
_____

15. Do you plan to buy a license for 1992 (next year) ?

_____yes_____no

16. How old are you? _____years.

17. How many years of crabbing experience do you have? _____years

Thank you for your time.

Return to: Leonard Shabman
Department of Agricultural Economics
Virginia Tech
Blacksburg, VA 24061-0401

SURVEY 2: 1992 PROFILE OF THE FISHERY

Joe Crabber
123 Pot Lane
Chesapeake, VA

Dear Joe Crabber,

In the fall of 1991, we conducted a survey of crab potters in Virginia. We appreciated your response to that survey, and we have enclosed a copy of the results. As part of our ongoing effort to develop a comprehensive understanding of the blue crab industry, we hope you would be willing to complete one other survey.

Protecting the Chesapeake Bay blue crab is vital for Virginia's watermen and the state. In the 1992 session, the General Assembly passed measures calling for mandatory reporting from all commercial fishermen and giving VMRC the authority to implement delayed or limited entry in some fisheries.

The Department of Agricultural Economics at Virginia Tech, with support from the Virginia Sea Grant Program, is preparing an important report on the economics of the Virginia blue crab fishery. We will be determining how the General Assembly bills and other policies might effect your income as a waterman. The main beneficiary of our work will be you, a crab potter in Virginia.

This survey is divided into two parts. Part I, in blue, contains general questions for everyone to answer. You need only answer Part II (green) if you hard crab or peeler crab potted in the month of September. If you did not crab pot in this month, please return the survey, leaving Part II blank.

Thank you for your time and assistance. Please return the survey in the postage paid envelope we have provided. If you have any questions about the survey, please feel free to call Anne Giuranna at (703) 552-5521. If you would like a copy of the survey results, please check the box on the back of the survey.

Sincerely,

Anne Giuranna
Project Manager

Joe Crabber
123 Pot Lane
Chesapeake, VA

Dear Joe Crabber,

Protecting the Chesapeake Bay blue crab is vital for Virginia's watermen and the state. In the 1992 session, the General Assembly passed measures calling for mandatory reporting from all commercial fishermen and giving VMRC the authority to implement delayed or limited entry in some fisheries.

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Thank you for your time and assistance. Please return the survey in the postage paid envelope we have provided. If you have any questions about the survey, please feel free to call Anne Giuranna at (703) 552-5521. If you would like a copy of the survey results, please check the box on the back of the survey.

Sincerely,

Anne Giuranna
Project Manager

Dear Survey Correspondent,

Two weeks ago a survey was sent to you about your crabbing activities during 1992. If you have already returned the survey, please accept our thanks. If not, we would appreciate you returning it today. Your response is vital to policy-making in the blue crab fishery. If you have any questions, please feel free to call Anne Giuranna at (703) 552-5521. You may call collect.

If you did not receive a survey or it has been misplaced, you will receive another one in about 2 weeks.

Thanks again for your help.

Sincerely,

Anne Giuranna
Project Manager

Joe Crabber
123 Pot Lane
Chesapeake, VA 12345

Dear Joe Crabber,

About four weeks ago, we sent you a survey about crab potting in Virginia. As of today, we have not received your completed questionnaire. We are writing to you again because your response is important to us as we try to discover how fishery policies will affect your income as a waterman.

We assure complete confidentiality. The return survey has an identification number on it for mailing purposes only. All responses to the survey will be aggregated, so that only averages for all crab potters will be reported.

This survey is divided into two parts. Part I, in blue, contains general questions for everyone to answer. You need only answer Part II (green) if you hard crab or peeler crab potted in the month of September. If you did not crab pot in this month, please return the survey, leaving Part II blank. Feel free to make any comments you have about the fishery on the last page of the survey.

In the event your survey has been misplaced, a replacement copy is enclosed. If you have already completed the survey and returned it, please accept our thanks. If not, we would appreciate you returning it to us today. Again, thank you for your time and assistance. If you have any questions about the study or survey, please feel free to call Anne Giuranna at (703) 552-5521. You may call collect.

Sincerely,

Anne Giuranna
Project Manager

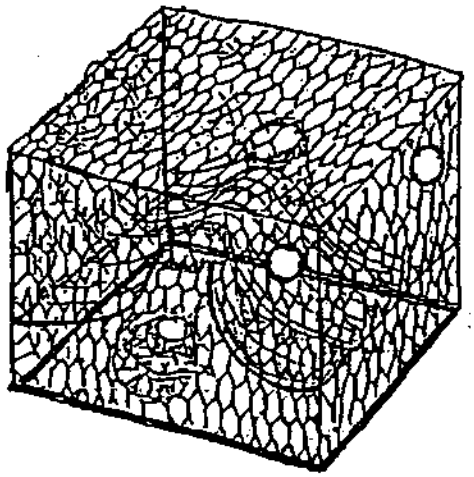
☐ IF YOU DO NOT HAVE A CRAB POT LICENSE OR DO NOT PLAN TO BUY ONE FOR 1992, PLEASE CHECK THIS BOX AND RETURN SURVEY

VIRGINIA TECH

1992 SURVEY OF

CRAB POTTERS

IN THE CHESAPEAKE BAY



PART I

GENERAL SURVEY

1. Currently Virginia is considering a mandatory reporting program and a new license fee system for commercial watermen. Other proposals to protect the fishery may be made. By responding to the following statements, you can express your thoughts about some of these proposals.

Please indicate whether you agree or disagree with the following statements:

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
There should be a limit on the number of crab pot licenses issued for hard crabs	1	2	3	4
There should be a limit on the number of crab pot licenses issued for peeler crabs	1	2	3	4
There should be better enforcement of size and catch limits	1	2	3	4
I am concerned about the winter dredge fishery in Virginia	1	2	3	4
Watermen do not receive fair prices for their catch	1	2	3	4
Most crabbers would be willing to report their daily catch to the VMRC	1	2	3	4
Most crabbers would be willing to provide price and cost information for their business to the VMRC	1	2	3	4

2. Now we would like to know about the boat you use for crabbing:

Age of vessel_____years

Length of vessel____feet

Age of engine____years Type of engine(circle one)

Inboard Outboard In/Out

Type of fuel

(circle one)

Gas Diesel

Estimated fuel use per hour _____gallons

In order to accurately represent the costs watermen face when trying to earn a living from crabbing, we would like you to give your best estimate for the following questions.

3. How much do you pay for boat insurance in a year? $_____

4. How much do you pay in docking fees in a year? $_____

5. How much do you pay for maintenance and repairs in a year?

Engine $_____

Boat $_____

Do you do this work yourself? (circle one)

yes no

6. Do you own a truck specifically for use in your crabbing operation? (circle one)

yes no (if no, skip to question 7)

Age of truck _____years

Mileage _____miles

Percent of mileage each year for your crabbing business

_____percent

Now we would like to know more about you:

7. How many years of crabbing experience do you have?_____

8. In what county do you live?_____

9. In what county is your vessel docked?_____

10. How old are you? _____years

11. a. What percent of your income comes from crab potting?_____

    b. What percent of your income comes from other fishing?_____

12. How many of the following do you normally fish per day? (please write in a number)

    _____ peeler pots

    _____ hard crab pots

13. On average, how many days per week do you do the following?

    hard crab pot _____ days per week

    peeler pot _____days per week

14. Please check each month in which you will **peeler pot** in 1992.

    ___March ___April___May ___June ___July ___August

    ___September ___October ___November

14. Please check each month in which you will **hard crab pot** in 1992.

    ___March ___April___May ___June ___July ___August

    ___September ___October ___November

PART II
MONTHLY SURVEY

IF YOU HARD CRAB OR PEELER CRAB *POTTED* IN THE MONTH OF AUGUST, PLEASE CONTINUE WITH PART II OF THE SURVEY. IF YOU DID NOT, PLEASE RETURN PART I OF THE SURVEY. THANK YOU FOR YOUR TIME.

There are over 2600 crab pot license holders in Virginia. You are one of only 100 people who are receiving a survey this month. The information you provide will be held in strictest confidence. We are only asking you to provide catch data for one month. This data will combined with all of the other responses from other months and only reported in this aggregated form, as an average for the industry. Your response is critical to the validity of the survey and to assuring that any new regulations are not an unneeded burden on watermen.

The following page contains a day-by-day calendar for the month of August. Two types of catch are listed - peeler crabs and hard crabs. Please give us your best estimate of the number of bushels of each that you caught each day.

August 1992

S	M	T	W	T	F	S
						1 bushels of peeler crabs_____ bushels of hard crabs_____
2 bushels of peeler crabs_____ bushels of hard crabs_____	3 bushels of peeler crabs_____ bushels of hard crabs_____	4 bushels of peeler crabs_____ bushels of hard crabs_____	5 bushels of peeler crabs_____ bushels of hard crabs_____	6 bushels of peeler crabs_____ bushels of hard crabs_____	7 bushels of peeler crabs_____ bushels of hard crabs_____	8 bushels of peeler crabs_____ bushels of hard crabs_____
9 bushels of peeler crabs_____ bushels of hard crabs_____	10 bushels of peeler crabs_____ bushels of hard crabs_____	11 bushels of peeler crabs_____ bushels of hard crabs_____	12 bushels of peeler crabs_____ bushels of hard crabs_____	13 bushels of peeler crabs_____ bushels of hard crabs_____	14 bushels of peeler crabs_____ bushels of hard crabs_____	15 bushels of peeler crabs_____ bushels of hard crabs_____
16 bushels of peeler crabs_____ bushels of hard crabs_____	17 bushels of peeler crabs_____ bushels of hard crabs_____	18 bushels of peeler crabs_____ bushels of hard crabs_____	19 bushels of peeler crabs_____ bushels of hard crabs_____	20 bushels of peeler crabs_____ bushels of hard crabs_____	21 bushels of peeler crabs_____ bushels of hard crabs_____	22 bushels of peeler crabs_____ bushels of hard crabs_____
23 bushels of peeler crabs_____ bushels of hard crabs_____	24 bushels of peeler crabs_____ bushels of hard crabs_____	25 bushels of peeler crabs_____ bushels of hard crabs_____	26 bushels of peeler crabs_____ bushels of hard crabs_____	27 bushels of peeler crabs_____ bushels of hard crabs_____	28 bushels of peeler crabs_____ bushels of hard crabs_____	29 bushels of peeler crabs_____ bushels of hard crabs_____
30 bushels of peeler crabs_____ bushels of hard crabs_____	31 bushels of peeler crabs_____ bushels of hard crabs_____					

IN THE SPACE PROVIDED PLEASE INDICATE THE NUMBER OF BUSHELS OF PEELER CRABS AND/OR HARD CRABS THAT YOU CAUGHT BY POTTING EACH DAY

If you peeler potted on any day in the month of August, please answer the following questions. If you did not, skip to the next page.

1. On the average, during August, how many peeler pots did you fish per day?
   _____ pots

2. What percent of your pots did you buy?

   _____percent

3. How many times a day did you pull your pots?____

4. How long did your daily crabbing run take?

   _____ hours

5. How many crew did you hire? ___ (if no,skip to no. 6)

   Did you pay your crew by wage or share?

   ____wage ____share

6. Did you shed your own peeler crabs during August?

   ___yes ___no (if no, skip to question 8)

7. What percent of your total catch of peelers did you shed?
   ____percent

   Which of the following did you use?

   ___floats ___recirculating system

8. Please indicate the percentage of your catch which went to each of the following channels during August:

   shedder _____percent personal use _____percent

   fish bait _____percent

   other (please describe) _____percent
   _____

If you hard crab potted **on any day** in August, please answer the following questions. If not, skip to the back page for any additional comments you wish to make.

1. On the average, during August, how many hard crab pots did you fish per day?
   _____pots

2. What percentage of your pots do you buy?

   _____percent

3. During August, how much bait did you use per day? _____

4. How many times a day did you pull your pots?____

5. How long did your daily crabbing run take? _____ hours

6. How many crew did you hire? ____(if none, skip to no. 7)

   Did you pay your crew by wage or share?

   _____wage ____share

7. What is the lowest price at which you would be willing to sell your crabs?

   $_____

8. Please indicate below any reasons other than low price which would cause you to not crab on a given day:

9. Please indicate the percentage of your catch which went to each of the following channels:

   Picking house _____ percent

   Sold live to other than picking house _____ percent

   Sold steamed to other than picking house____percent

   Sold as picked meat _____percent

   Personal use _____percent

   Other (please explain) _____percent
   _____

ADDITIONAL COMMENTS:

☐ IF YOU WOULD LIKE A COPY OF THE SURVEY RESULTS, PLEASE CHECK THIS BOX

PLEASE RETURN SURVEY TO:

ANNE GIURANNA
DEPARTMENT OF AGRICULTURAL ECONOMICS
VIRGINIA TECH
BLACKSBURG, VA 24061-0401
(703) 552-5521

1. Production functions were not estimated for the months of March, October, and November because no surveys reported any peeler crab catches in these months.

2. The 1990 list was used as the 1991 list of license holders was not available from the VMRC at the time of sampling.

3. Many people who filled out Part II of the survey (monthly data) filled out everything except the monthly calendar. These surveys were not considered incomplete because they provided much other useful information. Incomplete surveys included only those who did not fully complete Part I (general data).